THE HAWAIIAN PLANTERS' RECORD

Volume XXX. JULY, 1926 Number 3

A quarterly paper devoted to the sugar interests of Hawaii and issued by the Experiment Station for circulation among the Plantations of the Hawaiian Sugar Planters' Association.

Entomologists' Report on Termite Problem*

By F. Muir and O. H. Swezey

Termites have interested the Station entomologists from the foundation of the Station and observations on the species and their distribution have been made from time to time and published in the *Record* and in the *Proceedings of the Entomological Society*. Specimens have been in the Station collection for many years.

Their interest in this question was greatly increased in 1913 when a species of *Coptotermes* was first found in the Territory, as it belongs to a group which forms large nests in the ground and are most destructive on account of their numbers and fondness for wood. The genus *Coptotermes* also contains species which are known to attack living plants, sugar cane among others. At that time the entomologists pointed out that the presence of this insect in the Islands would alter the whole aspect of our termite problem and in time would place it in the forefront of the insect problems facing the Territory.

Mr. David Fullaway, of the Territorial Board of Agriculture and Forestry, undertook to investigate these insects and so the Station entomologists, while following his work and assisting in every way, have published very little on the subject.

Until recently the general public and, strange to say, the builders and architects have evinced slight interest in the subject in spite of the warnings of the entomologists, but the destruction in several large buildings and dwelling houses has recently brought the question more forcibly to their notice.

Recently some of the entomologists invited some of the lumbermen, architects and builders to meet at the Pan-Pacific Institute in Manoa and discuss the matter together, and this led to several recommendations regarding buildings and experiments to test the resistance of various woods and the effectiveness of preservatives. Another meeting is to be held very shortly to report progress.

We have two termites in the Territory of economic importance, *Cryptotermes piceatus* and *Coptotermes formosanus*.

* Prepared at request of the H. S. P. A. Trustees.

Cryptotermes Piceatus

This insect has been in the Territory for over twenty years, the first record being in 1904; before this date they were confused with *Kalotermes immigrans* under the name of *Kalotermes marginipennis;* the exact date of its introduction is therefore not known. The winged adults swarm at certain times of the year and the sexes mate. They then retire to a suitable place to start a new colony. A hole or crack in a piece of wood, or a small space between two pieces of wood, is a favorite location to start their home. The colony increases slowly and never becomes very numerous. This is the species found so frequently in houses, posts, fences and furniture. The attics are favorite places for them; they enter through the ventilators and the rough lumber of the rafters contains ideal nesting sites. Their presence is generally noticed by the small pellets of excrement looking like fine shot or rough, uniform sawdust.

We require more detailed knowledge of the distribution of this species. At present it is known all over Oahu, but it is likely to be distributed throughout the Islands.

On account of the smallness of the colonies the work of destruction is slow, although in time it is very thorough. Good paint together with absence of holes and crevices in woodwork is the best preventative. On rough wood, paint and preservatives are best applied by an air gun or air brush as the liquid then penetrates into holes, cracks and crevices much better than when applied by a brush. The ventilators of houses should be screened with insect proof wire.

Coptotermes Formosanus

This species swarms during certain times of the year in much larger numbers than the last mentioned. The newly mated couple find a place of refuge in the soil, in preference alongside a post or other woodwork in or on the ground. At first the female is active and attends to the eggs and young herself, but as the first generation grows up they take over this work and the female devotes herself entirely to laying eggs. A cell is excavated in the ground by the workers and the female remains therein, her abdomen increasing in size till it is larger than one's thumb. She is unable to move and is fed and attended to by the workers, the eggs being taken off by the workers and stored in other cells and attended to till they hatch. The fecundity of the female is colossal and she lives for several years. A colony once formed and the female having reached this condition, the numbers increase rapidly, and food in the shape of wood must be found to keep it going. In the search for food the workers tunnel through the ground for long distances. In an African species these tunnels have been followed for 300 yards. When dead wood is absent *Coptotermes formosanus* and *Coptotermes gestroi* (two very closely related species) will attack living plants.

An ordinary wooden building near a large nest can be damaged to a point of danger in less than a year.

The presence of this species can often be recognized by the mud-like cement with which they stop up holes and cracks in the wood they are working in.

So far the distribution of this species is throughout Honolulu and extending into the residential districts of the several valleys. Isolated occurrences have

been found at Oahu Sugar Company, one on the peninsula below Waipahu and one on the mauka side of the plantation just below the Waiahole ditch. It is also known at Kuhio wharf, Hilo, Hawaii.

There are four records of this species attacking living sugar cane. In 1917, on the peninsula at Oahu Sugar Company; in 1920, in Mr. Caum's garden, Makiki; November, 1924, in the mauka field of Oahu Sugar Company, and in March, 1924, at the Experiment Station grounds, Makiki. In all these cases termites were found attacking wood a short distance away.

There are two lines of attack against the damage done by these insects, first to protect our woodwork against attack, and second to kill off the nests.

The first is a mattter for the architects, builders and lumbermen, and economy will have to be a ruling factor. The use of metal to insulate buildings has been used successfully elsewhere. Wooden houses must be built on piles and these capped with metal discs and no woodwork from the building should be brought in contact with the piles or the ground. Brick, stone, cement, etc., houses can be insulated by a strip of metal about a foot or two feet above the ground, projecting for an inch or so on the outside. Concrete foundations are good if properly made and care is taken to seal up all holes caused by pipes, wires, etc., passing through. Lime cement is useless as the termites can pass through it as easily as through wood.

Paints and preservatives may be of help and several are being tried out and others have been sent for by Lewers & Cooke, Ltd., and other business men interested in the question.

The destruction of the nest is by fumigants and poisons. Arsenate has been found successful with some species. The success of insoluble poisons is chiefly due to the habit of termites to devour their own dead. Carbon bisulphide can be used to destroy nests, but its success depends upon the nature of the soil. Its economic use over large areas is questionable. Over small areas where it is desirable to erect a house it is very useful. The presence of termites in soil can be discovered by driving wooden posts into the ground and examining them a few months later. When termites are present then the spot can be fumigated with carbon bisulphide.

Termites as a Sugar Plantation Pest

These insects can affect plantations in two ways. First, by directly destroying sugar cane and secondly, by destroying woodwork, such as buildings, flumes, fences, ties, etc.

As a probable sugar cane pest the Station entomologists consider that the evidence at present available indicates that these insects will not play an important role. The four isolated cases recorded above all showed that the nests were in nearby woodwork. Similar isolated cases will happen, more frequently than in the past, but they are not likely to be of primary importance.

The reason for this conclusion is that in Formosa, Muir found that these insects did damage only in those regions recently cleared of forest trees and the old stumps allowed to remain. These stumps were all the sites of nests and in the dry season the termites attacked the surrounding sugar cane, most probably for moisture. A similar condition exists in the rubber plantations in Malaya

where *Coptotermes gestroi* attacks living rubber trees. *Coptotermes formosanus* have been present on the Station ground for a number of years and only on one occasion, when very large cane was growing under very favorable conditions, have they been known to attack cane. Over the greater portion of our plantations there is no woodwork of any kind, no dead stumps and seldom living trees, so there are few places for new colonies to start. Also the presence of our little common ant, *Pheidole megacephala,* in numbers in our cane fields is a good protection against the starting of new colonies.

As destroyers of property both species must be considered, and as *Coptotermes* gets established over larger areas precautions will have to be taken similar to what must now be taken in Honolulu. This is a problem which must be worked out by builders and entomologists together.

Biological Control

This question has been kept till the last as it is the most difficult to deal with. So far as we can see at present there is little hope along this line as we have so little information. Recently one of the Station entomologists was asked if he would recommend the Legislature to appropriate money to introduce parasites of termites into Hawaii and he replied: "No, for if he knew of any such he would ask the H. S. P. A. Trustees to send a man at once to procure them, and not wait for the Legislature."

In the tropics where these insects are numerous nearly every insectivorous animal will devour termites if they can get at them. In Java, a fungus is known to destroy whole nests. Nematode worms have been reported as destroying termites. It is possible that we might find something to work effectively in some part of the world, but the search will be long and success exceedingly uncertain.

Our own common ant (*Pheidole megacephala*) plays a very important part in checking the spread of termites. Nothing in the way of animal matter comes amiss to these ubiquitous little scavengers and termites form a dainty dish. Innumerable small colonies, before they can get well established deep in the soil, must be destroyed by them. In the mauka field of Oahu Sugar Company where termites were found eating living sugar cane some railway ties were found infested with small colonies. *Pheidole* were already found attacking these and a few weeks later when we examined the ties again the termites were all cleaned out by the ants.

Mr. Pemberton has been asked to make whatever observations he can on termites in the Malays.

Recommendations

It has been stated above that a meeting has already been held between the entomologists and others who are interested in this question, and another will be held shortly.

It would be good if a standing committee could be formed including a couple of entomologists, representatives of the lumber business, architects, builders and any others who are seriously affected by these insects. This committee could supervise and report upon such experiments, etc., as are recommended. Entomologists by themselves can do but little in this matter.

To acquire more information as to the distribution of these insects plantation carpenters can help by sending in specimens of woodwork attacked by them, along with specimens of the insects.

There is talk of asking the Board of Agriculture and Forestry or the next Legislature to pass a rule or law prohibiting the movement of wood attacked by termites. This idea should be discouraged for the following reasons:

Prohibitory laws always breed resentment and unless distinct good can come of them they should not be enacted. *Cryptotermes* has been with us for over twenty years and as it can be taken about in furniture, packing cases, matting and many other things as well as building lumber it must be widely distributed by now and a prohibition on the movement of old building lumber and not on other means of distribution would be illogical. It is much better to educate builders, and others, to the danger of using such lumber in reconstruction or building. The habit of *Coptotermes* nesting in the ground makes the probabilities of specimens ready to form nests being carried in lumber fairly remote. There is as much chance of conveying a young nest in a potted plant or in a roll of matting.

But, should the inhabitants on Kauai, Maui, Molokai, etc., where these two termites are not known to be at present, consider that they should be protected, then regulations might be passed covering this feature, although such regulations will be more psychological than materially effective. When these insects are known to be on these other islands then the regulation should be repealed.

Although the Station entomologists have published very little on this subject they have never lost sight of it. It has been discussed on many occasions by the Hawaiian Entomological Society and its importance is thoroughly recognized by all entomologists in the Territory.

Termites, or White Ants, in Hawaii

Considered from the Plantation Standpoint

By David T. Fullaway

Entomologist, Board of Agriculture and Forestry

Introduction

The damage to wood, woodwork and wood products caused by termites or white ants has been increasing noticeably from year to year in the city of Honolulu, and the losses that have been experienced thus far, amounting to hundreds of thousands of dollars, and those that are almost certain to occur with the passage of time, give occasion for serious thought.

Termites are not new insects here. As early as 1883 two species were known[1]. One of them was later said to have done great damage to wooden buildings in the city of Honolulu[2].

The extraordinary increase of wood destruction is due to the entrance at Honolulu of two additional species[3], one vastly more prolific than the precedent

1 *Neotermes connexus* and *Kalotermes immigrans.*
2 F. H., ii (2), p. 88, and Intr., p. clxxiv.
3 *Coptotermes intrudens* and *Cryptotermes piceatus.*

species, the other better adapted to conditions here. They are presumed to have come in oriental commerce not long before or after 1900. These species in the quarter century supposed to be here, have spread and completely occupied the city of Honolulu. They have also occasionally been found in isolated communities elsewhere[4], notably in Hilo. These species will be referred to in this account as the soil-nesting termite and the dry-wood inhabiting termite.

Nature of the Termite

Termites are social insects, living in communities of larger or smaller size. The location or home of the community is usually referred to as a nest or a termitarium. Individual members of the community are only in the smallest

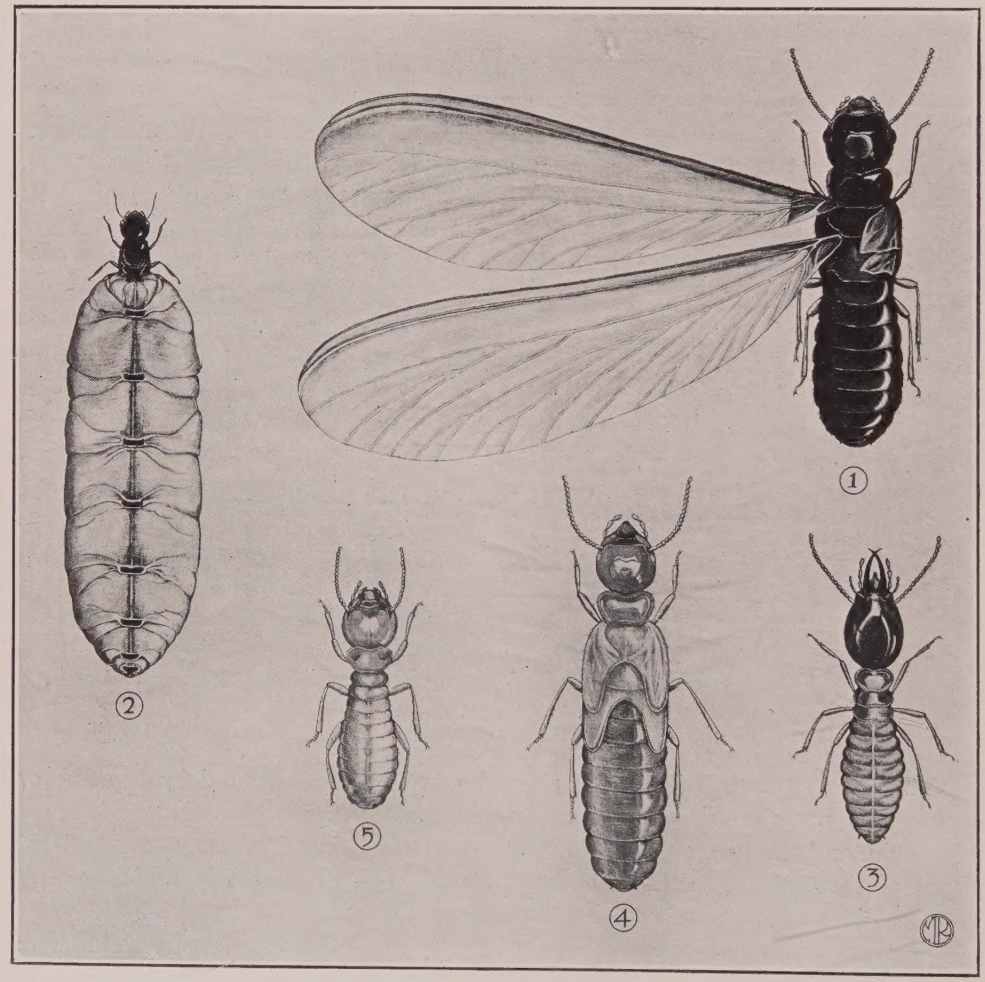


Fig. 1. Illustrating the Soil-nesting Termite (*Coptotermes intrudens*). 1—Winged adult; 2—Queen; 3—Soldier; 4—Nymph of winged form; 5—Worker (x ca. 7 except 2 which is x 2). (Original.)

[4] Hilo and Oahu Sugar Co. Plantation, mauka and makai lands.

degree independent. The biological unit in these insects is not the individual but the society, and their ways are better understood with this fact in mind. The development of social life among the insects has led to a division of the labor of the society and the rise of castes among the individuals. The termite community usually consists of a queen, soldiers and workers. Young or immature forms as well. The queen produces eggs, which become fertilized in passing from her body; they are extruded on to the floor of the nest and hatch after the lapse of a few days. The young thus emerging are at first undifferentiated larvae, but later develop characteristic marks and eventually become adults, either winged or wingless. The wingless forms are the soldiers and the workers which never develop sexually and are hence said to be sterile. The winged forms, on the other hand, are fully developed male and female adults and are sometimes referred to as the fertile or sexed forms. These latter occur in large numbers at certain times and after a preliminary period of inactivity in the termitarium, leave in a body or swarm, indulge in a nuptial flight, pair, drop their wings, and if able, engage in the foundation of a new community, the male impregnating the female,

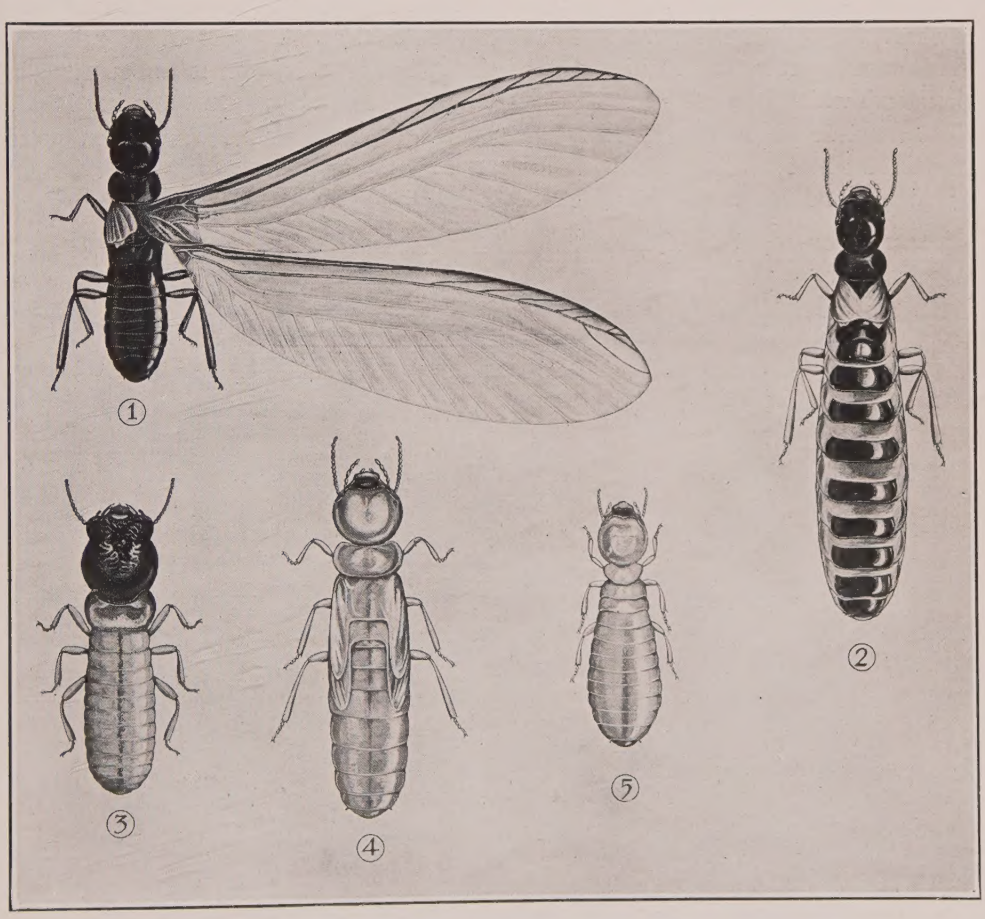


Fig. 2. Illustrating the Dry-Wood Inhabiting Termite (*Cryptotermes piceatus*). 1—Winged adult; 2—Queen; 3—Soldier; 4—Nymph of winged form; 5—Young nymph (x ca. 7). (Original.)

which then develops into a queen. Until the first workers are produced, the male and female must provide for themselves and young, but later the workers do everything, except in the special fields of reproduction and defense, which are the respective functions of the king and queen and the soldiers. The nuptial flight may occur at any time of the year, but the largest emergence of winged forms is in the spring. The flights occur just after dark in Hawaii. This is the critical moment in the termite's life, for thousands of pairs perish where one succeeds in finding shelter and protection from enemies. Termites shun light; exposure to the sun's rays is inimical to them and if long continued proves fatal. They are easy prey to the black ant when their excavations or galleries are broken into and exposed, for their bodies are soft and easily pierced by the powerful jaws of the ant.

Peculiarities of the Soil-Nesting Termite

The soil-nesting termite is apparently hypersensitive to a dry atmosphere and depends on the soil moisture to obtain suitable humidity in its galleries. When it works above the natural level of the soil it often corrects a lowered humidity by carrying soil particles from below into the aerial ramifications of its galleries. This peculiar moisture requirement of the soil-nesting termite is undoubtedly a handicap which has retarded its progress here considerably. On the other hand, its spread has been greatly facilitated by the continuous line of wooden poles used for supporting electrical conductors, all of which have their butts buried in the ground and otherwise give shelter and protection to the colonizers of the soil-nesting species. This species undoubtedly got a foothold here somewhere along the waterfront and spread gradually along the thoroughfares of the city

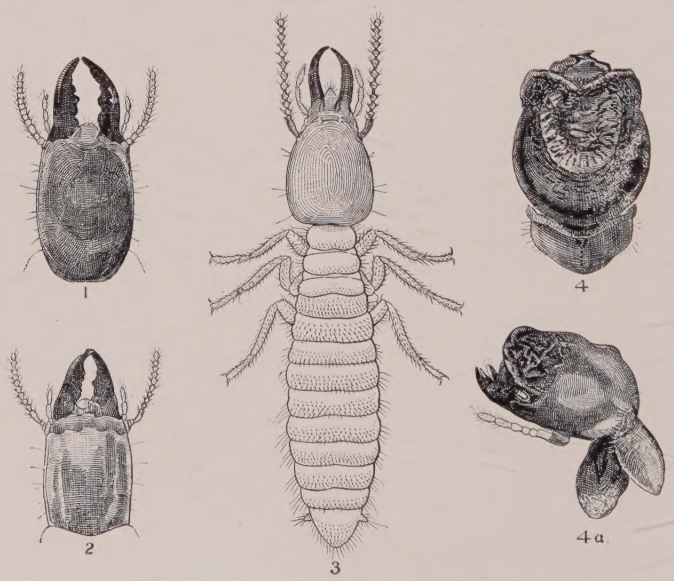


Fig. 3. Illustrating the Soldier form of Hawaiian Termites. 1—Head of *Neotermes connexus* x 5; 2—Head of *Kalotermes immigrans* x 5; 3—*Coptotermes intrudens* x 9; 4—Head of *Cryptotermes piceatus* x 11; 4a—Same, lateral view. (The Hawaiian Forester and Agriculturist, Vol. XVII, No. 10, Plate I, opposite p. 296.)

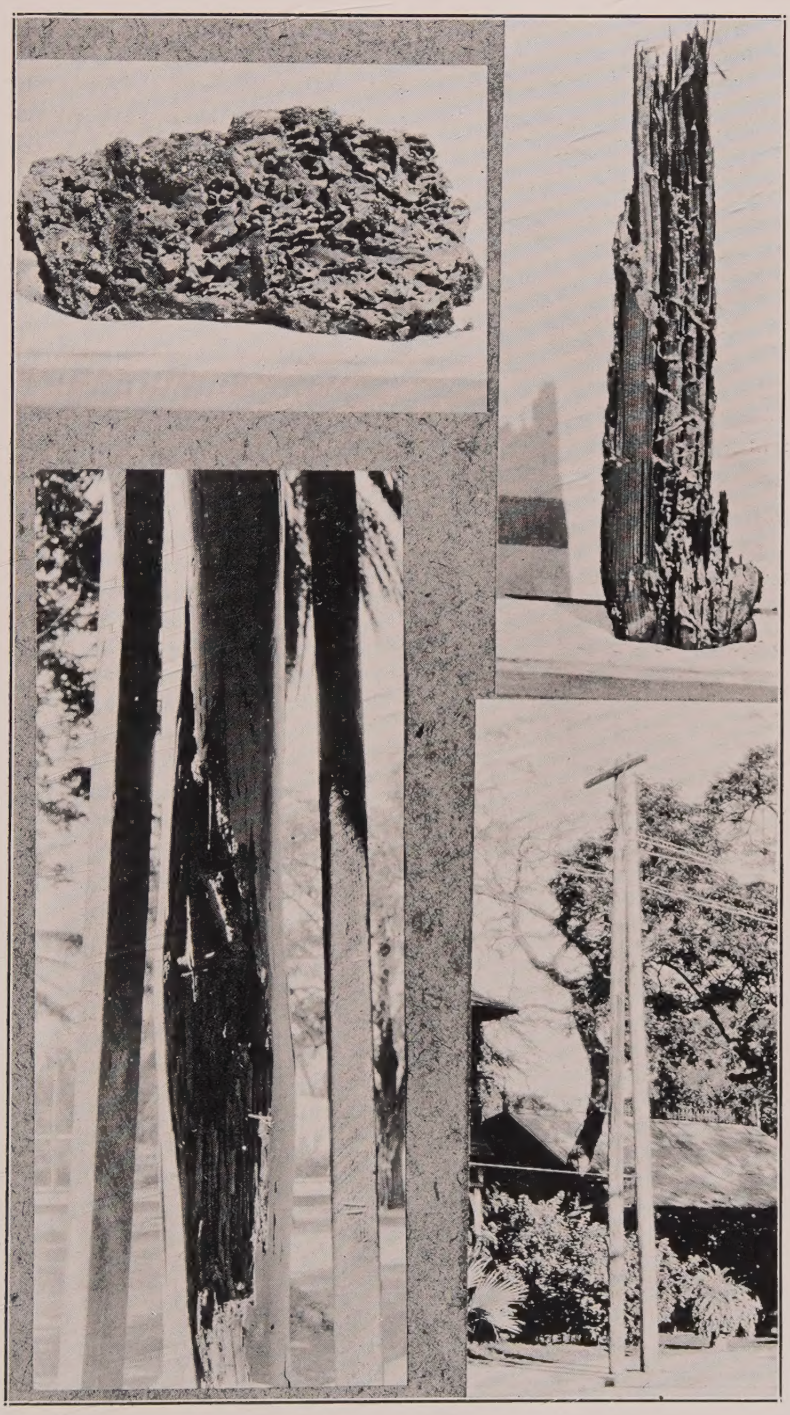


Fig. 4. Illustrating the destructive work of the soil-nesting termite (*Coptotermes intrudens*). Upper left—Portion of the termitarium composed of earth, excrement and saliva; Upper right—Section of damaged timber showing hollow core; Lower left—Supporting column in former Capitol bandstand ruined by this species; Lower right—Telephone pole damaged by it (reduced). (Original.)

by means of the poles. Occasionally a fence post or building would be invaded, but these occurrences are isolated ones and lack the continuity of the pole infestations. As the spread of the soil-nesting species has been outward and gradual it is reasonable to assume, and the facts appear to bear out the assumption, that the down-town sections are the most densely populated, the communities becoming less numerous and populous away from the center.

The significant feature in the biology of the soil-nesting species is the large size the communities are able to reach. Two to three hundred thousand is a low estimate of the number of individuals disclosed in breaking into an average-sized termitarium. In the establishment of a community, progress is slow at the beginning, but after the first year the community grows very rapidly. It is enabled to do so by a remarkable secondary or late-in-life growth which takes place in the queen, probably stimulated by the development of the sexual organs subsequent to coitus. The queen thus attains relatively enormous dimensions (one inch or more in length), but the increase in size only directly affects the abdomen, as it is due mainly to the increased development of the ovaries and fat body. Egg production increases at the same time and it is no exaggeration to say that at the height of its powers one of these queens lays from 500 to 1,000 eggs a day. With a daily increment such as this over a long period, it is no wonder that these communities become so populous and devastating.

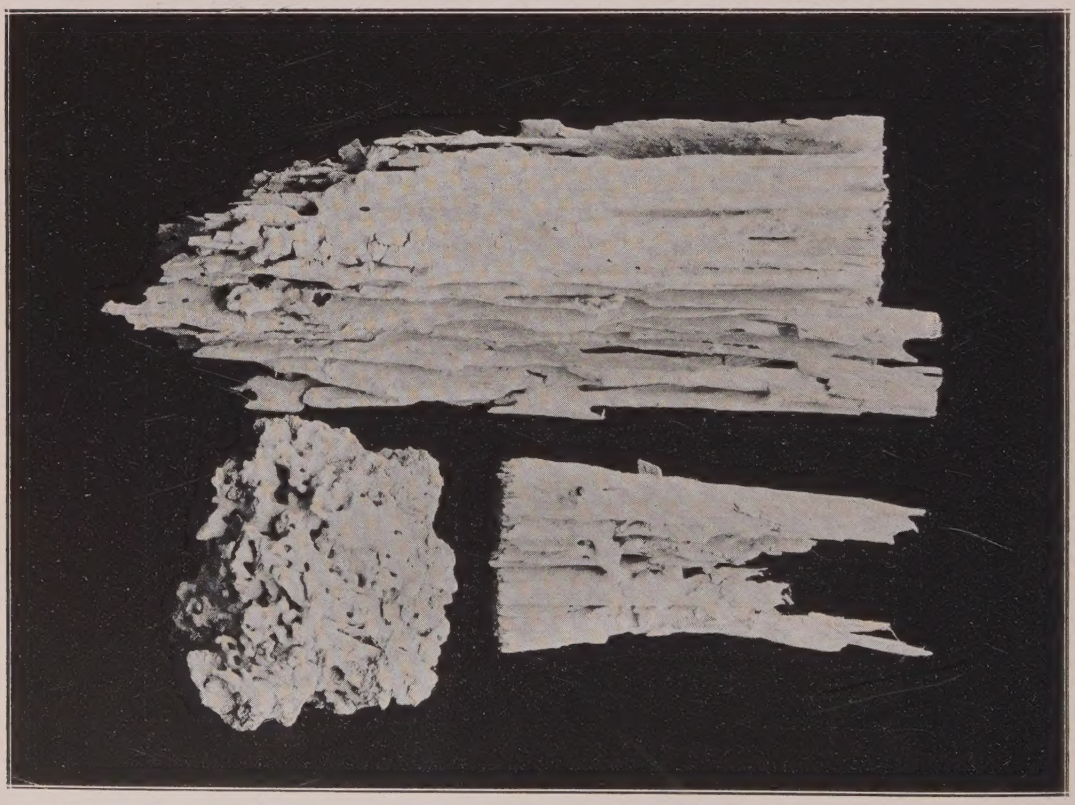


Fig. 5. Illustrating the destructive work of the soil-nesting termite (*Coptotermes intrudens*). Interior portion of damaged timbers exhibiting the replacement of cellulose by a composite of earth, excrement and saliva which has scarcely any tensile strength. (Reduced). (Original.)

Fig. 6. Illustrating the work of the soil-nesting termite (*Coptotermes intrudens*). Runway constructed on supporting timber and leading from underground nest to frame-work of dwelling-house in Honolulu. (Reduced.) (Original.)

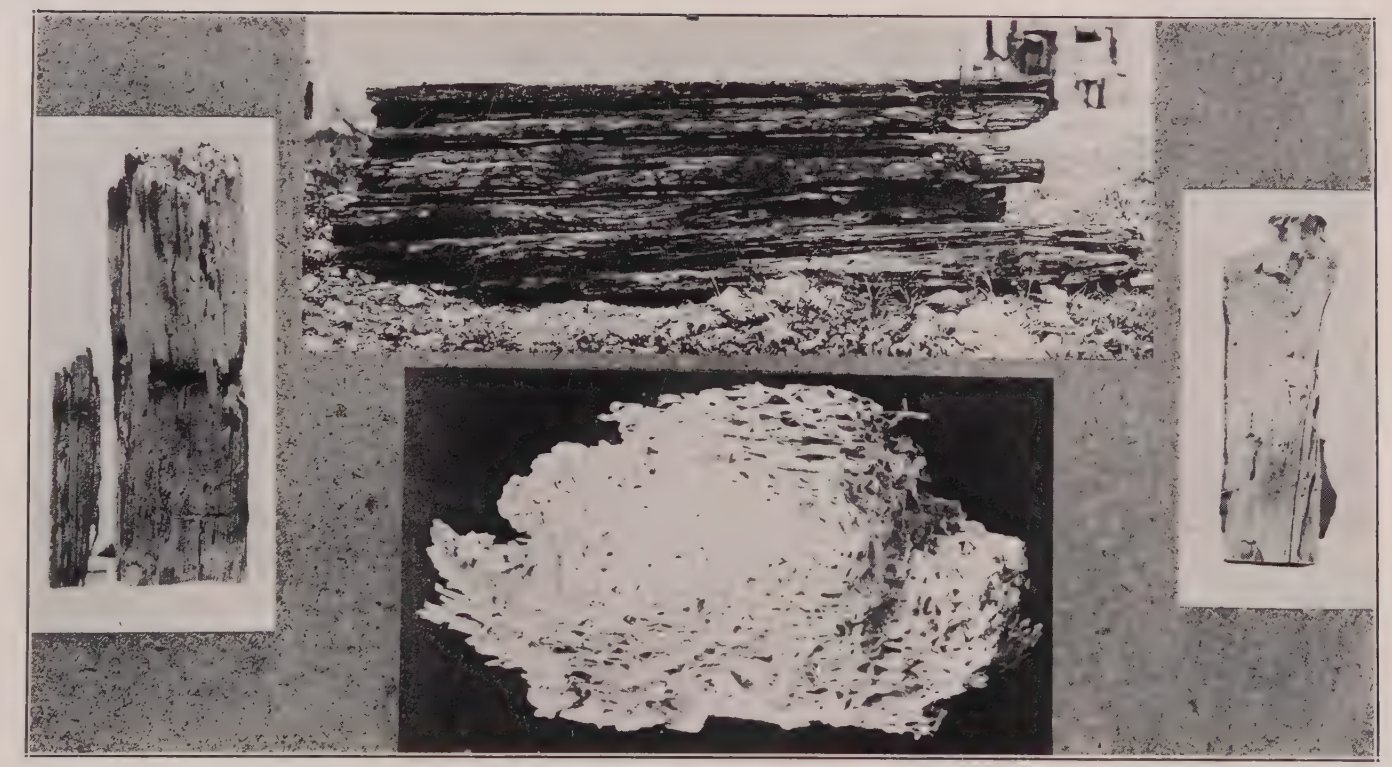


Fig. 7. Illustrating the destructive work of the three lowland species of termites in Hawaii. Center, that of the soil-nesting termite (*Coptotermes intrudens*) damaged railroad ties above, interior portion of damaged timber—a termitarium—below; Left, that of *Kalotermes immigrans*—a damaged timber; Right, that of *Cryptotermes piccatus*—an infested wood sample. (Reduced.) (Original.)

Foraging is often necessary in rapidly expanding communities and quite frequently run-ways are discovered which cannot be traced to a nest owing to the friable nature of the soil through which they extend or to a devious passage through rock, concrete, etc., which appears to be impervious but really is not. When obliged to run on an exposed surface, as they are sometimes between crevices, a covering of earth or fecal matter is constructed to protect them from the light and sundry enemies and at the same time preserve the correct circumambient humidity. The discovery of such covered run-ways generally leads to the unmasking of an extensive infestation.

The soldier of the soil-nesting termite has a yellowish brown head and sickle-shaped mandibles; it is quite ferocious, and emits an acrid whitish fluid from the front of the head when disturbed. All the forms appear to be a trifle larger than the corresponding forms of the dry-wood inhabiting termite, and a trifle hairier. The wing venation of the adult sexed form is, of course, quite distinct.

Peculiarities of the Dry-Wood Inhabiting Termite

The dry-wood inhabiting termite is principally a house-infesting species. It is found in the frames of the house and to some extent also in the supports. It likewise infests floors and ceilings, mouldings, picture frames, furniture of all kinds and wood products generally. The communities of this species are quite small, averaging about 100 individuals; but on account of the adaptability of the species to dry wood, which is used so extensively here for dwellings, and the ease with which new communities are initiated, it is a very close second to the soil-nesting termite in destructiveness.

The nest of this species is very simple. A slightly widened gallery in the dry wood serves the purpose. The queen never reaches very large size and produces relatively few eggs. The communities are established in the usual way by a mated pair of sexed adults which have, subsequent to the nuptial flight, found shelter and protection from enemies, dropped their wings and settled down to work. The infestation of wood with this species, however, is always direct, as the nest is in the wood and the communities are not so populous that foraging must be resorted to. Access is obtained by a boring of 1 mm. diameter. Once inside, the boring is enlarged somewhat and the excavation of galleries is begun. These are extended lengthwise, that is, with the grain of the wood, and widened in places. Short galleries, connected by borings, are the rule rather than one long continuous excavation of a uniform cross section.

The castings of this species are quite characteristic, consisting of tiny compressed pellets, and as they are occasionally ejected from the nest or excavation through a boring, falling in a heap or scattered mass directly below the point of ejection, an indication is given of the presence of this termite in the wood. All borings and excavations opening externally are soon closed with a characteristic chocolate-colored, parchment-like curtain.

The soldier of the dry-wood inhabiting termite is quite distinct in appearance. The head is large, thick, excavated in front, and characteristically sculptured on top, generally black. The winged forms are small, with narrow wings, which have a characteristic venation. It is not known where the dry-wood inhabiting

Fig. 8. Illustrating the destructive work of the soil-nesting termite (*Coptotermes intrudens*)—Supporting timber of a large tenement in Honolulu, so badly damaged by this species that the structure collapsed in the severe wind storm of December, 1918. (Reduced.) (Original.)

termite got a foothold here, but it is widely distributed and most thoroughly established everywhere. There is hardly a house in Honolulu which they have not infested.

The Termite Problem as It Affects the Plantation

The termite problem is acute today in Honolulu and in a smaller way in Hilo. It affects principally the holders of improved property. Public service corporations, dealers in goods subject to attack and the government are also concerned. It is no problem for the plantations at present, but what about the future? Unquestionably these two new and extraordinarily destructive species, which are now confined to the cities, will eventually spread into the country, and isolated communities will be established in suitable spots. It is questionable that they will be able to do the damage to cane here that they do in other cane-producing countries where the environmental conditions are more favorable. However, no pains should be spared to destroy nests as they occur on plantations. Likewise suitable measure should be taken to prevent their access, as far as possible. In time it is possible that plantation mill sites, residential quarters, warehouses, villages and camps will furnish locations for termite activities. A problem will then exist for the manager similar to that confronting the city property-owners today. The following suggestions are offered:

Watch carefully for the appearance of both species in the settlement as well as in the field. Act promptly to eradicate an infestation. Carbon bisulphide can be used against the soil-nesting species after the nest has been located. It is applied as a soil-fumigant through a piece of one-inch pipe into a hole a foot deep directly over the supposed site of the nest. The hole should be filled with dirt after pouring in the carbon bisulphide and the ground tamped.

Do not anticipate the natural spread of the dry-wood inhabiting termite by bringing second-hand lumber to the plantation from the city and thus introducing it. Such lumber is almost certain to be infested and is known to be capable of carrying this particular species into a new locality.

All alterations and repairs to old buildings and all new building should be planned and carried out with the termite menace in mind. The day of attack can thus be anticipated and damage and loss prevented.

For instance:

Inasmuch as termites live almost exclusively on wood, the substitution of other material will give the greatest measure of relief from their attacks.

On the other hand, it has been proved possible to isolate the woodwork of a building from the soil-nesting termite by the use of a concrete slab between the ground and the wood, with proper attention to detail in the formation of the slab and the arrangement of connections above and below. The slab should be moderately thick (6 in.) and well reinforced. The concrete mixture should be especially good, and care should be taken in the laying and drying to avoid cracks, pores, etc. The problem of ground settlement should be taken into consideration. A finish of cement on the upper surface of the concrete slab will serve to fill indistinguishable crevices.

Fig. 9. Illustrating the destructive work of the dry-wood inhabiting termites (*Kalotermes immigrans* and *Cryptotermes piceatus*)—Damaged timbers in former county jail, Honolulu. (Original.)

The further removed the woodwork is from the ground the better, as opportunity is thus given to observe the run-ways of possible invaders.

It is possible to protect the upper portion of a building from infestation of termites moving along run-ways when use is made of a thin metal cap on all foundation walls and piers, the cap projecting about one inch beyond the vertical surface and having the edges turned down sharply. This device is extensively used in Australia and protects the buildings from sudden attack, anyway. The guards need some watching, however.

The same protection can be secured in cheaper buildings by raising the building off the ground, using solid concrete piers 4 or 5 feet in height as supports, with termite guards on top. Or more simply, a 4 in. concrete cube with termite guard on top, can be inserted under all present underpinnings. At the same time, however, steps must be isolated from the building or placed on a concrete slab with termite guard. Likewise all screens enclosing basement areas, vine trellises, etc., must be removed away from the building, and they should preferably be constructed of metal lath; if made of wood, they should be underlaid with a concrete slab having termite guard at the top. If these suggestions are followed the building would be reasonably safe.

Some measure of protection will follow the treatment of wooden supports with such ant repellants as creosote, crude oil and kerosene or carbolineum. Treatment of the ground with the same materials, using them at the rate of 1 gallon to every 6 square feet, is also recommended as a protection to the building.

Fig. 10. Illustrating the destructive work of the dry-wood inhabiting termites (*Kalotermes immigrans* and *Cryptotermes piceatus*)—Damaged woodwork of dwelling-house in Kakaako. (Original.)

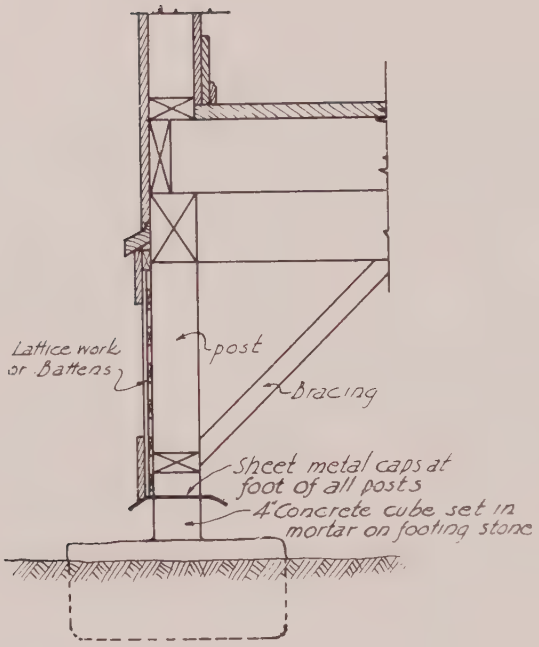
All the above measures anticipate the eventual appearance of the soil-nesting termite on the plantations. When infestations actually occur, the nest should be sought first, naturally, and a charge of 8 oz. of carbon bisulphide put into the ground over it to kill the queen.

Protection against the dry-wood inhabiting termite must be sought in a different way, as this species infests wood directly. Perhaps the greatest protection will be obtained by treatment of the wood. An entirely satisfactory treatment to make wood termite-proof has not yet been discovered. Creosote is perhaps the best preservative, but it cannot be used on interior finish, furniture or other wood products of common use, on account of the so-called "bleeding" which follows and the resulting inability to paint over it with satisfactory paints. Corrosive sublimate and zinc chloride are good preservatives and particularly suitable for interior finish but are not considered generally useful on account of the danger of poisoning as a result of their use. Corrosive sublimate, phenol, alcohol and shellac (corrosive sublimate 50 gms., phenol 50 gms., alcohol 2 liters, liquid shellac 4 oz.) make a good mixture, and the danger of poisoning just mentioned is in this case obviated by the shellac.

Resistent timbers, of which there are a few, would be useful, but they are difficult to obtain and expensive.

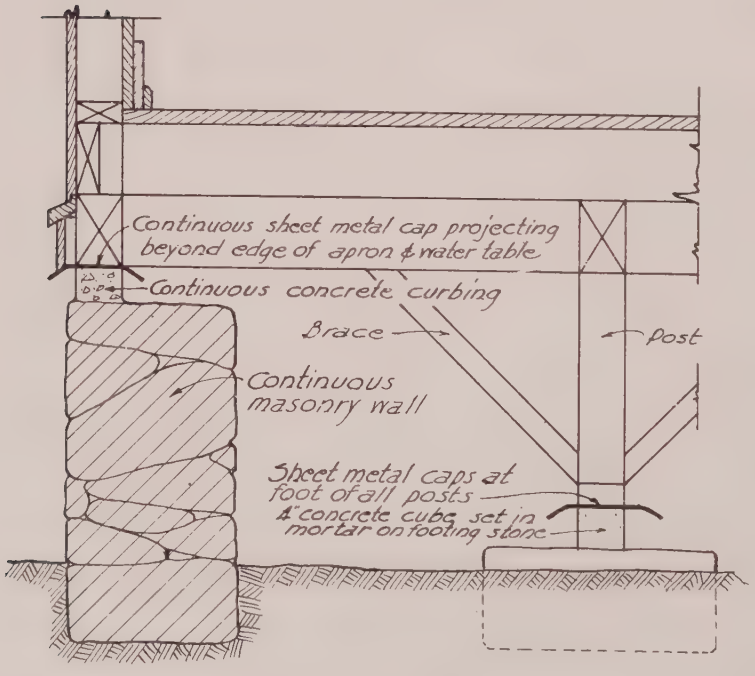
There is no question about the value of a good heavy coat of paint as a preservative.

The thorough screening of houses particularly of attics, will help materially in reducing the incidence of infestation. Infested attics can be treated with a mixture of crude oil and kerosene 50-50, care being taken, by laying newspapers, to prevent the drip going through the ceiling.



Typical Construction for Small House on Wood Posts

Fig. 11. Illustrating a method of termite-proofing a wooden building. (Original.)



Typical Construction for Continuous Stone Wall Foundation

Fig. 12. Illustrating a method of termite-proofing a wooden building. (Original.)

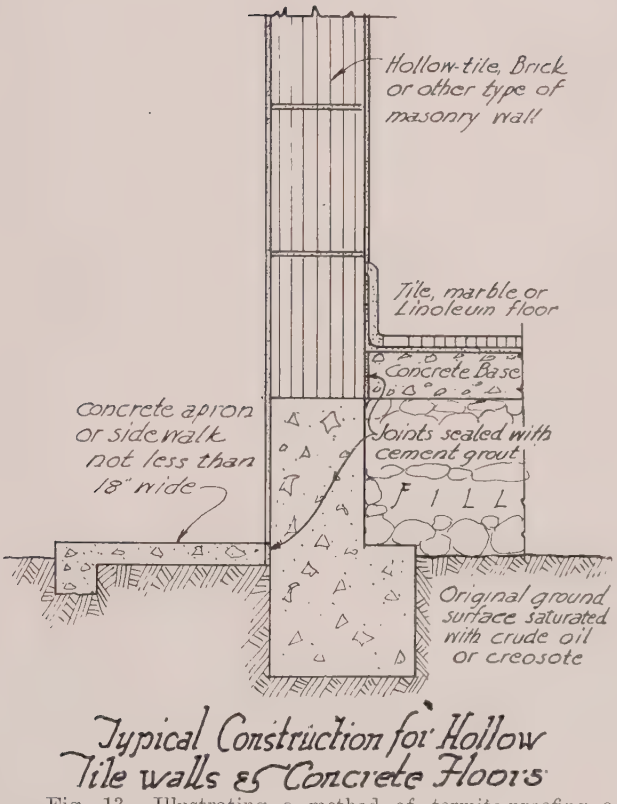


Fig. 13. Illustrating a method of termite-proofing a building. (Original.)

Trapping the winged forms flying inside a building by turning off all the lights in a room save one, and placing a white wash-bowl underneath, filled with water, is also a commendable practice.

Furniture and other wood products infested with dry-wood inhabiting termites can be fumigated with carbon bisulphide in a fumigating vault or chamber to rid them of infestation. Another method of accomplishing the same result is to expose the objects to strong sunlight for five or six hours.

Exotic Trees in Hawaii

By H. L. Lyon

Melaleuca leucadendron: This promising tree which has come to us from Australia is known in its native land under the following names: Paper-bark tree, White Tea-tree, Broad-leaved Tea-tree, Swamp Tea-tree, Cajeput-oil tree, Nectar tree, Gelam tree, Atchoourgoo, Bethar, Bichunia, Kyenbooree, Morngi, Numbah, Oodgeroo.

We consider "Paper-bark tree" the most appropriate name for its designation in Hawaii and hope that this name will be adopted here in preference to the others.

The most striking feature of this tree is its white bark, which is composed of innumerable, superimposed layers that can be peeled off like sheets of paper. In this respect, it resembles the well-known paper birch of North America. *Melaleuca leucadendron* is much more prolific in the production of paper bark than is the paper birch, however, for young trees in our cultures only 2½ inches in diameter had developed bark fully ½ inch thick, while trees 6 and more inches in diameter possessed bark well over an inch thick. This excessive padding of the trunk with lifeless bark enables these trees to withstand the heat of grass and brush fires. Only the outer, loose layers burn or char and the heat never reaches the living tissues which lie next the wood. It seems that grass and brush fires often run through groves of these trees in Australia, and Maiden (1:91) holds that these circumstances are responsible for the rather contradictory scientific name which was applied to this tree, for he explains as follows:

Melaleuca. From two Greek words *melas*, black, and *leukos*, white, because the trunk of the first tree described was black and the branches white. The explanation probably is that trunk and branches were alike papery and white, but that the trunk (as is often the case) was charred by a fire, giving it a blackish appearance.

The paper-bark tree is said to range from Queensland in Australia north through the Malay Archipelago to Burma. Australian botanists tell us that it is a very variable species and they recognize several well-defined varieties within the confines of their own country. These varieties range from shrubs or small trees with rigid, erect branches to tall trees with slender branches which are often drooping. Maiden (1:96) describes it as a tree "up to 40 or 50 feet, and a diameter of 1 or 2 feet in central and coastal New South Wales, but attaining a large size as Queensland is approached," and Baron Von Mueller (181) writes, "This tree attains a height of 80 feet, with a stem up to 4 feet in diameter." Its natural habitat in Australia is said to be along the coast in moist, sandy localities. It is very tolerant of salt and Von Mueller recommends it for planting "in salt swamps where no eucalyptus will live."

The paper-bark tree affords products of considerable value to man. The Cajeput oil of the pharmacists is obtained through distillation of the leaves and young twigs. The pronounced insulating properties of its bark render this of commercial value and large quantities are now being shipped to Europe from the Orient to be used as insulating material about refrigerators and steam pipes. The wood has merits that should make it especially attractive to us here in Hawaii if it really has the properties claimed for it by the authorities quoted below:

The wood is fissile, hard, close-grained, regarded as almost imperishable underground, and resists the attacks of the termites. It is well adapted for posts, wharf-piles, shipbuilding, and various artizans' work.—Baron Von Mueller, pg. 181.

Wood of a pinkish colour, hard and close-grained, very valuable for underground work and wharf piles.—F. M. Bailey, pg. 67.

When worked, this timber smells like Brazil nuts. A close-grained, hard and durable wood. Brownish red in colour.—Wren Winn, pg. 19.

Melaleuca leucadendron, the White tea-tree, is an extremely pretty wood, with ripple markings and extremely durable in the ground.—Laslett and Ward, pg. 255.

Durable, cross-grained, . . . lasts well underground, resists white ants.—Ednie-Brown, pg. 28.

Excellent for fencing-posts in damp situations, being almost imperishable underground. —Nilson, pg. 5.

A paper bark tree growing in a forest planting above Wahiawa at about 1,100 feet elevation. At the time this picture was taken, the tree had been in the ground three and one-half years.

An illustration copied from Maiden's Forest Flora of New South Wales, showing botanical character of paper bark tree: *A*—Outside view of the flower opened out. *a*—Calyx. *b*—Petals. *c*—Stamens. *B*—Inside view of the flower opened out. *d*—Pistil. *C*—One staminal bundle with a petal. *D*—Stamens. *E*—Pistil. *F*—Ovary, showing convex summit. *G*—Vertical section of ovary. *H*—Cross section of ovary. *I*—Twig bearing fruits.

Burns well with a short, lively flame; heat expels resin; . . . *Grain.* Fine to medium, open; sometimes very sinuous, at others straight.—Herbert Stone, pg. 132-33.

Exceedingly hard and cross-grained, almost imperishable in moist places, but otherwise not of special merit; greatly used for ship timbers, boat knees and posts; wood much resembling that of the Melaleucas generally, very apt to crack and fly open on drying.—Maiden, 1:96.

The paper-bark tree was undoubtedly introduced into Hawaii many years ago, for there are now a few large trees to be found in widely separated localities. Apparently, it has never been planted extensively for all of the trees which we have thus far encountered occur in small groups or as isolated specimens. So far as we are able to judge, the trees now growing here are all derived from Australian stock, although they do not all display exactly the same characteristics. In its best form, it is an upright-growing tree with a straight trunk and a rather narrow crown. Most of our trees approximate this type.

A number of fruiting paper-bark trees are to be found in the forest plantings of the Board of Agriculture and Forestry in Manoa Valley. A few excellent specimens are growing near Mr. von Holt's mountain house at Palehua in the Waianae Mountains. Several trees have been planted along the roads leading to Kuhio wharf in Hilo and young plants may be found on the nearly naked lava in their vicinity which have grown from self-sown seed. Some of the largest and best specimens in the Islands occur on low land near the shores of Nawiliwili bay on Kauai. Mr. G. N. Wilcox owns the property on which they stand, and is, no doubt, responsible for their planting.

In December, 1919, we gathered seed of *Melaleuca leucadendron* from a tree in the Plant Introduction Garden in Miami, Florida, and the first lot of paper-bark trees reared at our nursery were grown from this seed. These trees were planted out in a great variety of situations and have done remarkably well, producing trees of good form. Some of them bore ripe seed when only four years old. Most encouraging results have been obtained with these trees in the thin, wet soil on flat-topped ridges where the native trees fail first and few exotic trees will grow. It would thus appear that the paper-bark tree can tolerate high concentrations of iron and aluminum salts as well as high concentrations of common salt. If this proves to be the case, this tree should be a suitable substitute in our forests for the native ohia lehua, to which it is more or less closely related.

Literature Cited

Bailey, F. M. Queensland Woods. London, 1899.

Brown, J. Ednie. The Forests of Western Australia and Their Development. Perth, 1899.

Laslett, Thomas, and Ward, H. Marshall. Timber and Timber Trees, Native and Foreign. London and New York, 1894.

Maiden, J. H. The Forest Flora of New South Wales. Sydney, 1904-1925.

Nilson, Arvid. The Timber Trees of New South Wales. Sydney, 1884.

Stone, Herbert. The Timbers of Commerce and Their Identification. London, 1918.

Von Mueller, Baron F. Select Extra-Tropical Plants Readily Eligible for Industrial Culture or Naturalization. Calcutta, 1880.

Winn, Wren. Timbers and Their Uses. London and New York, 1919.

Reports on Defoliation of Maui Koa Forests by Caterpillars

By O. H. Swezey

I hereby report on an investigation of insect injury to koa trees on Maui, January 13 to 16, 1926.

This investigation was made in company with Dr. H. L. Lyon, and Mr. F. Muir and Mr. R. H. Van Zwaluwenburg were with us on one day. It was made in response to Mr. H. A. Baldwin's reporting to Alexander & Baldwin, Ltd., that the koa forest above Haiku appeared to be seriously affected. Mr. Baldwin took us to the region on January 13.

Lying to the eastward of Olinda, at an elevation of 3,500 to 4,500 feet, is a large area composed largely of koa trees with lehua trees scattered among them and several other kinds of smaller native trees. From below, this forest area had the appearance of being dead, as the branches were devoid of foliage. On arriving at the forest and examining the koa trees, it was found that they had recently been defoliated by caterpillars. Isolated trees in gulches somewhat separated from the main forest were found to be not entirely defoliated, in some cases scarcely at all injured, and in others with a few branches which still bore foliage. From these, specimens of the caterpillars were obtained which were responsible for this extensive denudation of the trees. Their presence and the evidence of their work on these partially defoliated trees was sufficient to assign this as the cause for the extensive defoliation. They are a looping caterpillar, or measuring worm, about 1½ inches long when full-grown, varying in color from green to grey and reddish brown.

Most of the caterpillars had finished their eating and completed their growth and had disappeared. Much search was made to secure a good supply of the caterpillars to rear them and obtain the mature moth so as to determine what was the species and whether it was a new pest or a native insect. Search was also made for the pupae or chrysalids which the full-grown caterpillars form in the process of developing from caterpillar to moth. Quite a good number of the chrysalids were secured from beneath moss on logs, in and under trash on the ground, and in the soil a little below the surface. Old chrysalids from which moths had already issued were found beneath bark of tree trunks also. From the material brought to the Experiment Station, some of the moths have already matured so that we are now able to determine the species. It is *Scotorythra paludicola,* a native moth known to occur on Kauai, Maui and Hawaii. It is a brown moth with wing expanse of from 1 inch to 1½ inches. The forewing has a dark spot near the middle and two more or less wavy dark lines crossing it, and a few dark dots towards the outer extremity. The coloration varies a good deal and some specimens have a dark band across the middle of the wing occupying all the space between the wavy lines.

Koa moth, *Scotorythra paludicola.* Series of moths showing variability.

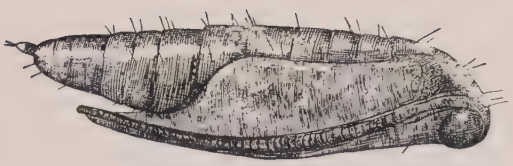
The Kula pipe line trail penetrates the denuded koa forest, and one day we followed this trail to see if the conditions were the same throughout. Along this trail, going easterly, the limits of the koa forest are reached in about three miles. The koa trees were found defoliated for the entire extent. Even the farther easterly trees were found to be defoliated like the others. These caterpillars have not attacked the other trees of the forest, except that a very few mamani trees were noted and they were defoliated by the same kind of caterpillars as were the koas.

Such an extensive defoliation of koa trees had not been observed before by any of the people of the region with whom we talked, but Mr. Pogue, of Kailua, said that he had seen a similar occurrence about thirty years ago. We made the trip one day to Keanae on the new road. Not many koa trees were to be seen near this road, but just beyond Mr. Pogue's place at Kailua a few were observed in the gulches and on ridges, and these were practically in perfect foliage. However, by diligent search I was able to secure a few of the same kind of caterpillars that had occurred in such countless thousands on the koa forest at the higher elevation*.

Dr. R. C. L. Perkins, in the *Introduction* to the *Fauna Hawaiiensis,* in discussing the habits of certain of the Lepidoptera, says, "*Acacia koa* is attacked by numerous species, and certain of these become locally and periodically so numerous, that great areas of koa forest are entirely denuded of their phyllodes. *Scotorythra idolias* on Hawaii and *S. paludicola* on Maui were responsible for two of the most severe attacks that we have witnessed. Native birds attracted in thousands by the abundance of this, one of their favorite foods, were gorged to repletion, and the starving caterpillars formed in writhing masses on the ground beneath the tall koa trees. The dropping of excrement from the trees on the dead leaves beneath made a rattling noise as of a hailstorm. In one instance it was noted that these pests of caterpillars were destroyed by an epidemic fungous disease, which attacked the full-grown larvae after their descent to the ground for pupation, as well as the pupae themselves."

Thus it is seen that the defoliation of koa forests, similar to the present one on Maui, have been known at least a few times before. No doubt it has occurred more often than attention has been called to it, or it may have occurred in less degree more frequently and not severe enough to be noticed. At any rate it is a native species of insect that is responsible in this case, a species that has developed in the Islands using the koa as a host plant, just as many other species have developed using other kinds of the forest trees as hosts. In most cases these insects do not increase to destructive numbers, being held in check by natural enemies of several kinds. This is especially the case where the forests are in their natural conditions, not having been overrun by cattle or disturbed by man in any of his projects. Note that Dr. Perkins mentions above, "the thousands of native birds feeding on the caterpillars." In the present instance, only a very few native birds were observed anywhere in the forest. It is generally known that the native birds are much scarcer nowadays than they used to be. At present

* The species of moth that later issued from this lot of caterpillars was different, however. Its identity has not yet been made out.



Pupa of koa moth.

they are too scarce to be much of a factor in checking an extensive caterpillar outbreak.

A large predacious bug (*Oechalia grisea*) was found quite common on the koa trees where there were any remaining caterpillars. They pierce the caterpillars with the proboscis and suck the body fluids, thus killing them, and must have been an important factor in destroying thousands of the caterpillars.

A large native parasite (*Enicospilus mauicola*) was observed abundant at one place and a few were captured. This is known to be parasitic on caterpillars. A few of the caterpillars brought to the Station had the larvae of this parasite issue from them later on. Empty cocoons of the parasite were also found in and under moss and in the soil where the caterpillars had formed their pupae.

No evidence of the fungous disease mentioned by Dr. Perkins was found. It is a common observation in studying the native insects of the forests, especially in the wet regions, to find many that have died of fungous diseases. No doubt this is one of the important factors in the control of insects in the natural forests. The region at present concerned is a normally wet region, or at least bordering on a wet region. For some months it has been unusually dry weather there, perhaps too dry for this fungous disease to be effective, and this may be one reason for the extensive increase in the numbers of the caterpillars. No doubt the present situation has resulted from a succession of broods of caterpillars covering a period of a number of months, in which each successive brood has been an increase

Enicospilus mauicola, parasite of koa caterpillar.

over the preceding one, due to conditions being such that natural enemies were not operating to keep the insect normally checked. Probably several of the preceding broods have been quite destructive, but not sufficiently so as to be noticed until the last one, which has been so numerous as to result in this complete defoliation.

The koa trees are not dead yet as a consequence, but will be much checked, and probably there will be dying back of many twigs. As there has been considerable injury to the terminal buds the trees may be very slow to put out new foliage. This should be watched to see whether it results successfully, and also as to whether it is immediately attacked and destroyed by another brood of caterpillars. A new brood should be due immediately as there must be an enormous amount of moths matured already from the brood of caterpillars that defoliated the trees, for the pupae present in the ground when we were there must have all matured by this time, as those did which we brought back with us. These moths will be depositing their eggs soon, no doubt. It is just possible that if there is no foliage on the koa trees, the moths may go elsewhere in search of koas with foliage on which to oviposit. If they should oviposit on the defoliated trees, and the young caterpillars that hatch soon should not find any food (if no new foliage has yet formed) they will starve and thus bring about a termination of the trouble. However, if foliage has already started by the time a new brood of caterpillars appears, they would quickly destroy it, and this would result more disastrously to the trees, i. e., if new foliage should be eaten off as rapidly as produced, dying of the trees might be expected.

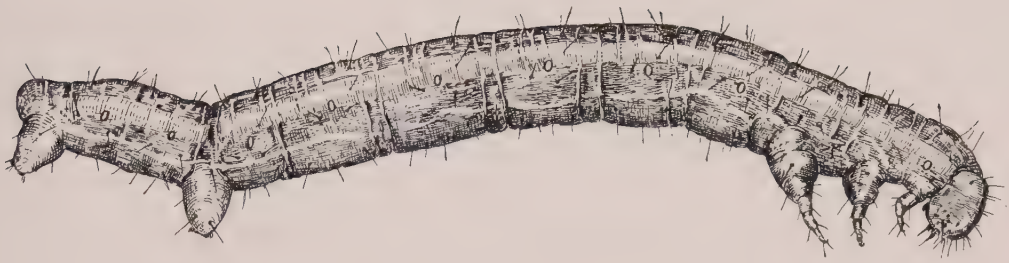
The situation should be carefully watched as to the ultimate outcome, and if possible determine the factors operating to bring about such conditions, or a continuation or repetition of such, if this is found to occur. It may require several trips at frequent intervals for a complete understanding of the situation.

If the scarcity of native insectivorous birds has been an important factor in the large increase of caterpillars, it points to the desirability of introducing forest-inhabiting, insectivorous birds to help bring back control of the caterpillars. Probably the Japanese titmouse, already well established in the mountain forests of Kauai would be quite useful. The food habits of this bird have not been studied, but they seem to be always searching for insects among the trees, and they are a lot more abundant than any of the native birds in the Kauai forests. It would be more feasible at present to introduce some of these birds to the Maui forests than to attempt introduction of other birds from foreign countries.

Another phase of the situation might be the consideration of dusting by airplane to poison the caterpillars, if there should occur a repetition of such an extensive outbreak in the region.

I hereby report on a second visit to the defoliated koa forest along the Kula pipe line eastward from Olinda, Maui, February 27, 1926.

There was no difference in appearance of the koa forest from what was present at my previous visit, six weeks before, January 13 and 14. No new growth had yet started on the defoliated trees. The tips of the twigs were dying back



Caterpillar of koa moth.

from 1 to 6 inches. It appears as though this had taken place several times before. On trees where there were still some vestiges remaining of the foliage, caterpillars were numerous in all stages, from recently hatched ones to nearly full-grown. As an indication of their abundance, twenty caterpillars were secured at one sweep of the net on a partially defoliated branch. Most of these were very small caterpillars. It indicates that the moths had matured from the previous brood of caterpillars and laid eggs which have hatched already and commenced their feeding on the remaining foliage of the koa trees. Apparently the most of them will starve to death unless they take to feeding on the foliage of other kinds of trees, for there is not enough foliage left on the koa trees to provide food for more than a few of them. Only a very few caterpillars were found on the other trees, however, and I could not distinguish whether they were of the same species or not. All that could be secured of these were brought in for rearing, in order to determine whether the same species or different species. These have not reared to maturity very successfully, but one moth reared from a *Cheirodendron* tree and another from *Coprosma* were of larger species than the koa moth. A few moths from caterpillers on ohia lehua trees are darker than the moths reared from koa (*Scotorythra paludicola*), but as the latter is a very variable species, I cannot be certain but what the moths from these two trees are the same species. However, if they are the same species, their caterpillars do not take to the lehua very well, for I secured only a few caterpillars from lehua with considerable effort. The lehua trees even in close proximity to the koa trees had no appearance of even partial defoliation by caterpillars.

On another day, a few caterpillars were collected from *Bochmeria* in Waihee Valley. The moths that matured from these very much resembled those from lehua above. They were not numerous enough to affect the trees at all on which they were feeding. The caterpillars did not resemble those obtained from koa at Olinda. No koa trees were to be seen in Waihee Valley, nor in Iao Valley, where I went also on another day.

By considerable digging in the ground, rotten logs, etc., in the Olinda forest, the empty pupa cases were found quite numerous, and only one living one was found. This indicates that the moths from the previous brood of caterpillars had practically all matured. Since they have such a preference to the koa tree, it is quite evident that most of the caterpillars that would hatch from the eggs they would lay would of necessity starve, since the koas are continuing in the defoliated condition. Perhaps this will result in checking the outbreak, so that

when the koa trees do eventually produce a new growth of foliage there will not be swarms of caterpillars to destroy it.

A few of the caterpillars brought in were found to be parasitized. Some by a Tachinid fly, *Frontina archippivora,* and some by one or more Ophionids of the genus *Enicospilus.* A few also succumbed to a fungous disease which is often very effective in killing caterpillars in the forests. Another caterpillar enemy that was abundant wherever the caterpillars were to be found was the predacious bug, *Oechalia.* There would be more of them, too, for their eggs were numerous. On the phyllodes of one small branch, I found five clusters of eggs containing 6, 6, 6, 8 and 10 eggs respectively. They were all about ready to hatch.

On March 2 to 4, I made a trip with Mr. Sam Baldwin, manager of Haleakala Ranch, to Waiopai, a tract of land on the south slope of Haleakala which the ranch utilizes. What forest there is, is chiefly above 4,000 feet elevation. The cattle roam as high as 4,000 feet, and what koa trees are left are in the gulches, hence do not form a continuous forest. These koa trees were not defoliated, though I found a few caterpillars on the foliage. They were mostly similar to those at Olinda, with a good proportion of green ones, but the larger number were of a reddish or brownish coloration, quite variable. The moths that reared from these were all the same as at Olinda, even from the green ones as well. Parasites and predators were present here also, as on the Olinda side of the mountain.

The foliage on some of these koas had a reddish tinge. This was found to be due to the presence of "red spider," a species of mite. Apparently these had been more abundant than at the time I was there, but it did not seem that the trees were very seriously affected by them. These mites were observed to some extent in the Olinda forest also. A few of the little black ladybeetle, *Stethorus vagans,* were found feeding on the mites.

Since making these observations on the koa trees on Maui, I have been giving attention to the koas on Oahu whenever there was opportunity. I have not seen any defoliation anywhere, but have secured two and three kinds of caterpillars*. They are always scarce. In all my experience in the forests of Oahu, I have never seen the koas defoliated by caterpillars. Once in 1911, I came upon a tree at the head of Pauoa Valley that had a good many caterpillars on it, and approached the nearest to defoliation of any that I have seen on this Island.

I wrote to Dr. Perkins about my January visit to the Olinda defoliated koa forest, and it will be of interest to quote from his letter of February 15, what he says about his observations on similar occurrences:

> In the early days of my collecting, I saw the koa trees stripped almost every year in one locality or another. In 1892, the trees of the wet belt in Kona—presumably by *Scotorythra idolias,* but I did not breed any; in 1893, I was not in any koa district, but in 1894 and 1895 the Haleakala forest of koa, 4,000 to 5,000 feet, was stripped for miles by *S. paludicola,* and in the latter year also all the dry koa forest near Kilauea (as also again in some later years) by *S. idolias,* though there may have been some *paludicola* also. In 1895 or 1896, all the koas at 3,500 feet were again stripped in Kona. In 1900, the koa trees on Tantalus were many of them quite stripped, but more than one species of caterpillar was

* From these, *Scotorythra rara* and *Scotorythra caryopis* issued in due time.

present, *metacrossa* being certainly the smaller and probably *rara* the larger species. I do not remember to have seen any total stripping of trees after 1900, but then I had not much opportunity later. Stripped koas generally at first put out leaves all over instead of phyllodes, and in bad cases get so weakened that *Plagithmysus* and *Neoclytarlus* beetles attack them.

I think I have recorded somewhere how the native birds in Kona—when birds were extremely abundant there—would gorge on these caterpillars till one might see individual birds so lethargic as to be scarcely willing to fly. When the mynah birds reached the height of their abundance in the forests, I believe the defoliation by these caterpillars really became much less frequent, but in 1892 it was a familiar sight to the old natives, who spoke of it as occurring frequently, though not necessarily every year.

From Dr. Perkins' experience, we can expect that the koa trees will recover in the Olinda forest. I expect, however, that many of them are likely to be so much weakened as to become a prey to other insects, and that it may result in the death of some of them, especially as the long drought has been somewhat detrimental to them anyway. I shall expect to make another trip to this forest in May or June to keep track of developments there.

I hereby report on a third visit to the defoliated koa forest at Olinda, Maui, May 13, 1926.

There is scarcely any difference in appearance from that of my previous visit, February 27. On those koa trees which had had some remaining foliage a little growth has taken place, and a few even are in bloom. But where the defoliation by caterpillars had been complete no new growth has started yet, except that occasionally in a tree are small bunches of numerous new twigs, scattered in the tree top. It is more apparent that there will be much dying back of twigs, and even larger branches, and possibly whole trees, but as to the final outcome time alone will tell. Already native beetles that attack dead or dying koa twigs, branches, or trees, are present. I found *Proterhinus* beetles on the dead twigs, and in small dead branches were the larvae of Cerambycid beetles, several species of which live in dead koa wood.

Caterpillars are scarce on koa now. Only a very few tiny caterpillars were found on any accessible foliage, where they had been numerous before. Search was made for caterpillars on the other kinds of trees and shrubs. Only an occasional one was found on anything except the native raspberry (*Rubus macraei*), a good deal of which is present in the region. The Rubus bushes had made considerable recent new growth, and the eating of the caterpillars was not conspicuous. However, by beating about with the insect net I was able to get a few caterpillars from the Rubus leaves most anywhere. These caterpillars looked the same as those that had previously been so numerous on the koa trees. I brought back quite a number for rearing the moths to determine if they were of the same species or not. None has been reared yet. The only one that has pupated had a maggot of the Tachinid fly, *Chaetogaedia monticola* in it. The pupa, however, resembled that of *Scotorythra paludicola* which I had previously reared from koa. *Mermis* worms issued from several of the caterpillars, resulting in their death. My remaining caterpillars give little promise of producing moths. Apparently the

change of climate, coming down to the dry hot climate prevailing in Honolulu of late has not agreed with them. Their food plant became exhausted also, and though they eat koa, which I have given them, they do not seem to thrive on it. It is of interest to determine the habits of the various caterpillars found in the Olinda forest, with special reference to the recent outbreak on koa, but to do this properly will require spending considerable time there at some convenient future time.

Losses Caused by Mosaic in H 109 Plant Cane

We have recently completed a test having to do with the effect of mosaic on the yields of H 109 plant cane. The test was in a field of an Oahu plantation. The work was carried on by Mr. Denison, of Waipio.

The field in question showed early signs of infection to the extent of perhaps 20 per cent in some areas.

In December, 1924, 50 average stalks were selected as nearly as possible of the same size. Half of these were healthy and half were diseased. None of the 25 original healthy stalks contracted mosaic during the period of the experiment, although they were in the immediate vicinity of the diseased stalks. Growth measurements were made every two weeks.

The experiment was harvested on April 28, 1926.

During this period the healthy stalks made 2.06 feet more growth than the diseased ones and each weighed three-fourths of a pound more.

Each stalk was run through the hand mill separately and the juice analyzed. Borer damaged stalks were discarded.

The following were the juices obtained:

	Weight per stalk	Brix	Pol.	Purity	Q. R.
Healthy	9¼ pounds	18.99	17.52	92.1	7.41
Mosaic	8½ pounds	17.42	15.35	88.5	8.57

We have, in this instance, a very distinct deterioration in the quality of cane caused by mosaic. This amounted to a decrease of 3.6 in purity and an increase of 1.16 in the quality ratio.

Assuming healthy cane as 100 per cent, we have constructed the following table showing losses to be expected if a field of H 109 were 100 per cent mosaic infected from the time of start:

	T. C. P. A.	Q. R.	T. S. P. A.
Healthy	100	7.41	13.49
Mosaic	92	8.57	10.73
Loss in Yield	8	1.16	2.76
Loss in Per Cent	8	15.6	20.5

J. A. V. and F. C. D.

The Identification of Sugar Cane Varieties

Owing to the large number of seedlings being propagated and tested on the plantations, a method of identification is needed in order to avoid confusion and possible errors that may prove costly. A practical means of identifying cane varieties by photographs is now being studied. In addition to picturing sections of the stalk, enlarged photographs of representative eyes or buds are made. The characteristic formation and hairing of the bud as pointed out by Jeswiet is thus taken advantage of without resorting to the slower and more expensive method of making pen and ink drawings. We show here, as examples of the work we are doing, the pictures of four varieties, the quarter-bred Uba seedlings bearing the numbers 25 Q 13, 25 Q 16, 25 Q 18, 25 Q 19. These are seedlings of U. D. 1 pollinated by D 1135. U. D. 1, in turn, is a seedling of Uba pollinated by D 1135. The seedlings therefore are one-quarter Uba and three-quarters D 1135.

While the stalks in the photographs show differences in each case, these differences are not such as to permit of ready identification and lack the striking contrasts so clearly brought forth in the enlarged bud photographs. These are such as to aid materially in distinguishing between different cane varieties even though the parentage, as in these instances, may be identical.

The pictures in each case are supplemented by descriptions which are filed with the photographs. For example, we give the description of one of them as follows:

Date: May 6, 1926.
Variety: 25 Q 19.
Place: Makiki Field 9B.
Age: 14 months—original stool.
General Appearance: Erect type.
Color: Young stalks, green; later, tan with red; little wax.
Eye: Prominent and humped.
Parents: U. D. 1 x D 1135.
Stalk: Fairly good; dirty.
Leaf: Erect, little overhanging, hairy sheath.
Top: Very weak; D 1135 type.
Stooling: Good, plenty of suckers.
Ratooning: ————————
Rind: Hard.
Disease or Pests: Borer.
Juice: 9.5 Q. R., ten months old.
Rating: Fair.
Remarks: ————————

The variety 25 Q 13 frequently has bud abnormalities, as shown in Fig. 1.

In future articles we shall report the progress of this study, using some of the seedlings that are showing up prominently in the plantation tests. In this instance, the canes pictured to introduce the subject were chosen for other reasons than their commercial significance.

T. S.

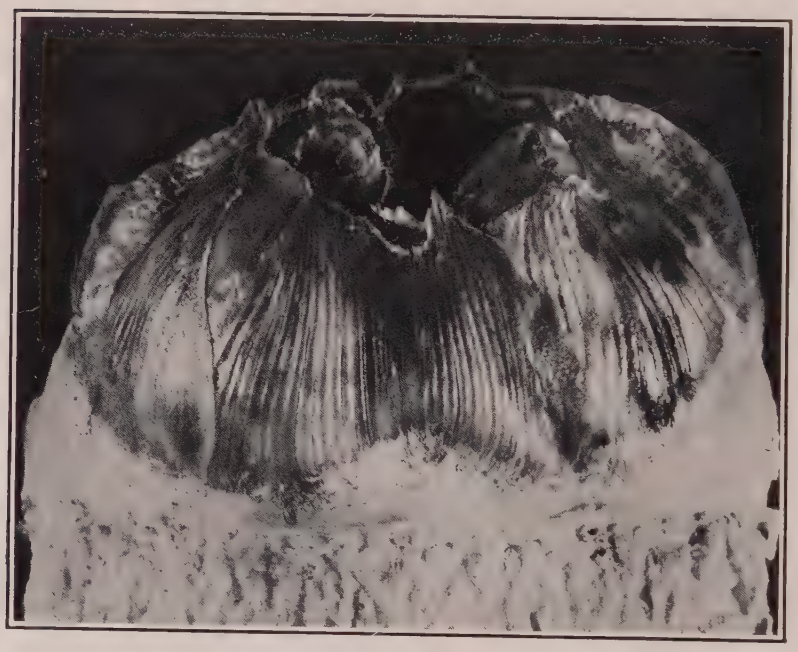
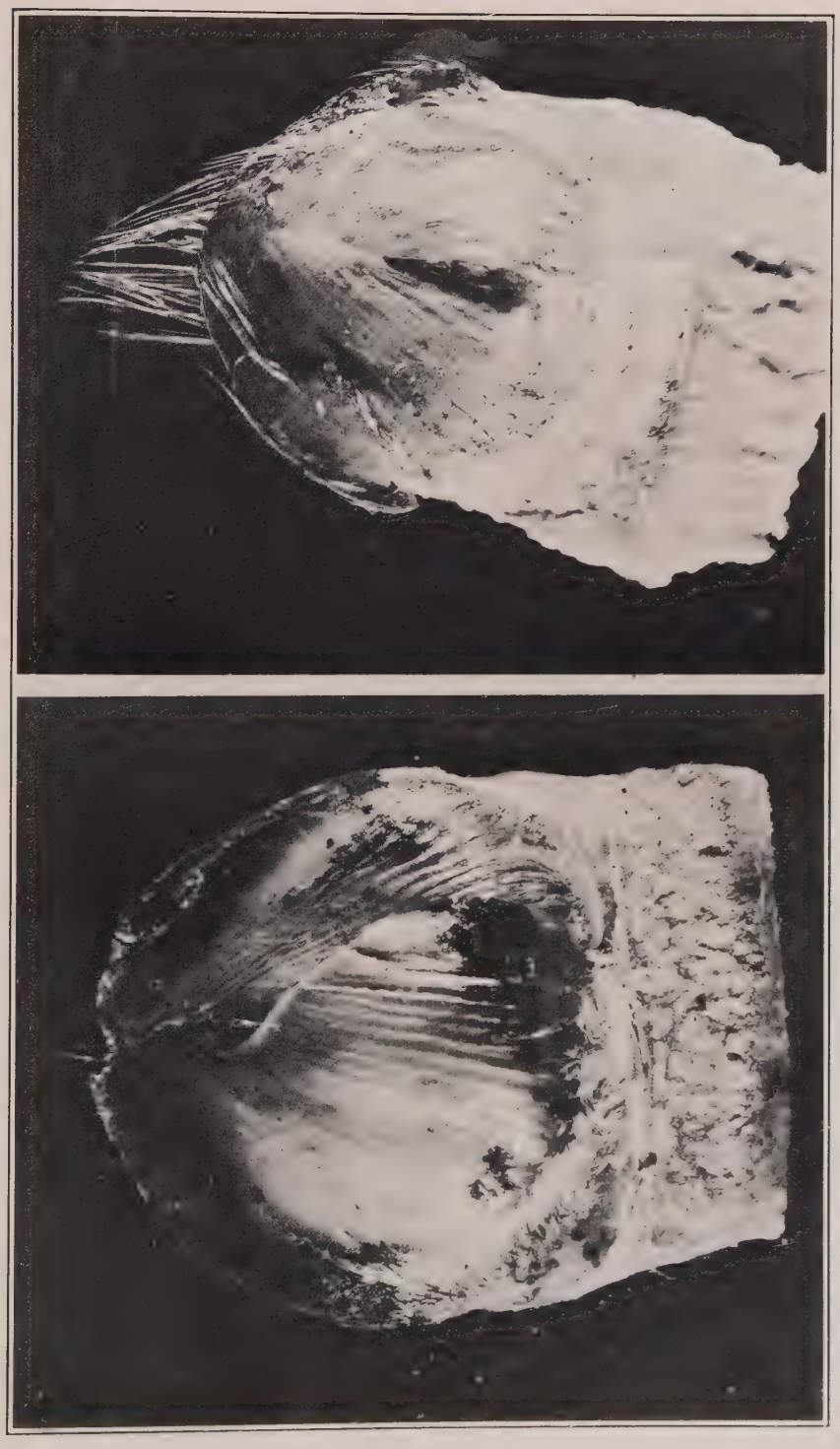


Fig. 1. 25 Q 13.



25 Q 13 25 Q 18

Fig. 2

25 Q 18

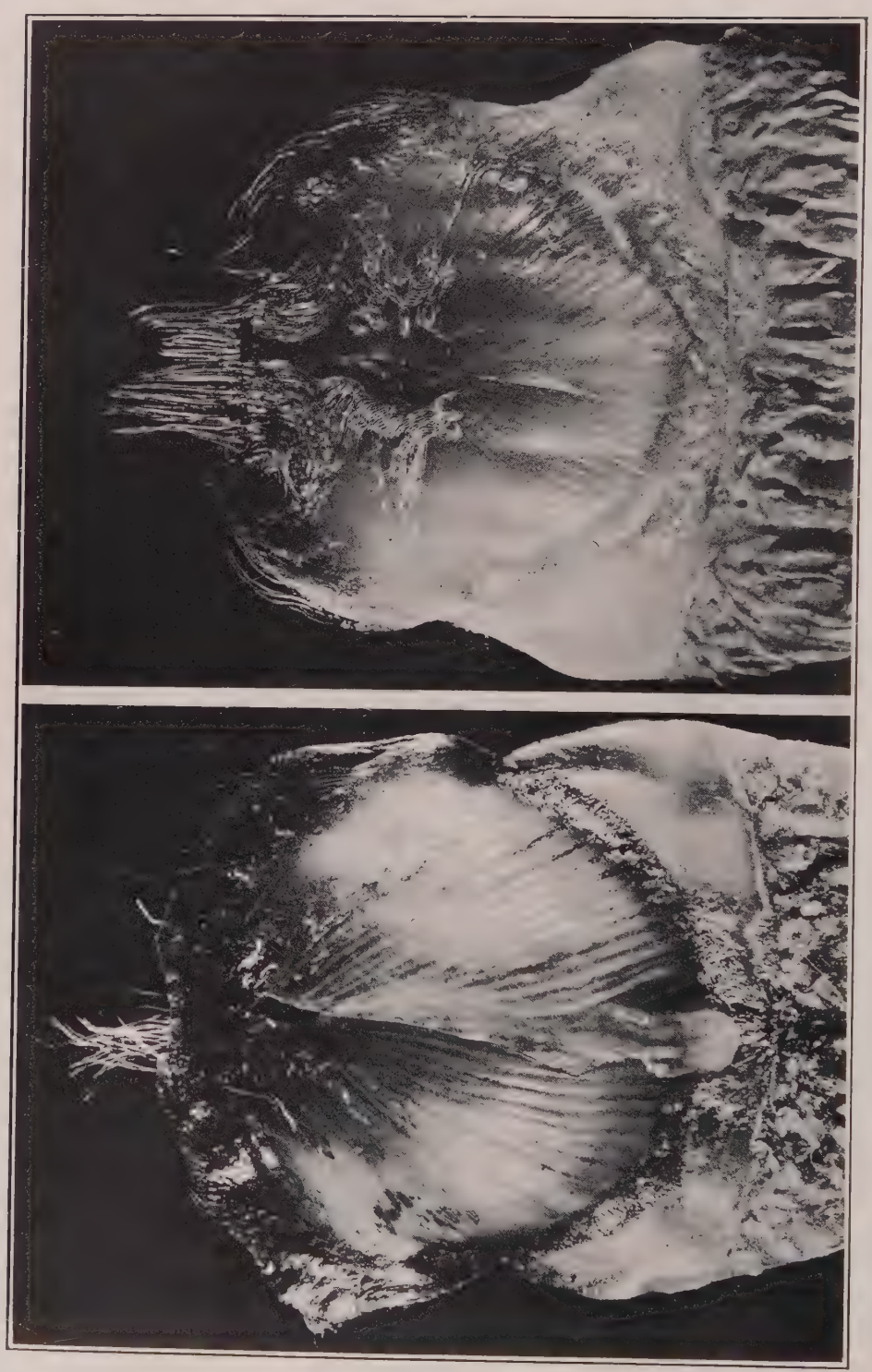
25 Q 13

Fig. 3

25 Q 19

25 Q 16

Fig. 4



25 Q 16 25 Q 19

Fig. 5

Uba Hybrids

By J. A. Verret

We give herewith data from a recent harvest of a number of Uba hybrids growing at Makiki. These data are not conclusive as they are based on 10-foot sections, with no repetitions, but they do give interesting indications of the value of some of these canes.

We give herewith a list of the more promising ones:

CANE FROM MAKIKI PLOTS—18 MONTHS OLD AT HARVEST EARLY IN FEBRUARY

Variety	Tons per Acre		
	Cane	Q. R.	Sugar
U. D. 100	108.0	10.44	10.35
U. D. 88	84.6	8.53	10.00
U. D. 75	113.3	11.40	9.94
U. D. 79	87.8	8.90	9.87
U. D. 106	97.9	10.23	9.57
U. H. 3	78.1	8.27	9.44
U. H. 2	70.7	7.76	9.12
U. D. 42	86.8	9.57	9.07
H 109	70.2	7.91	8.80
U. D. 23	79.1	9.02	8.77
U. D. 66	70.4	8.22	8.56
U. D. 39	64.5	7.56	8.53
U. D. 92	68.8	8.14	8.45
U. D. 1	60.8	7.22	8.42
H 109	60.3	7.23	8.33
U. D. 104	72.5	8.98	8.07
U. H. 1*	54.2	6.88	7.85

Several others of these canes are of promise, but as seed was taken we do not have comparative yields. Among these are U. H. 1, U. D. 58 and U. D. 62.

These canes have been sampled a number of times. As a whole they have poor juices. This applies especially to the Uba x D 1135 crosses. The Uba x H 109 has much better juice (see U. H. Nos. 1 to 4), and we feel that it is a more promising cross than Uba x D 1135, but it is much more difficult to obtain good H 109 pollen at the proper time. An exception to the above is U. D. 1, a cross between Uba x D 1135. We have found this cane to have consistently good juices.

Among the consistently poor juice canes are listed the following: U. D. 10, 11, 12, 14, 19, 21, 28, 31, 33, 34, 38, 41, 53, 57, 67, 69, 94, 95, 96, 101, 102 and 107. The very worst of these are: U. D. 14, 19, 31, 53, 57 and 101. We feel that the record of these particular canes shows them to have such poor juices as to be of no commercial value, and that they should not be spread on the plantations unless further careful tests show them to have worth while juices.

* Some seed taken from young cane.

QUALITY RATIOS OF UBA HYBRID CANES

Variety	Makiki Cane 18 Mos.	Makiki Cane not ripened	Makiki Cane 12 Mos.	Manoa Cane 14 Mos. Sampled in February
U. H. 1	6.88	9.33	8.3	9.4
U. H. 2	7.76	30.43	11.5	23.5
U. H. 3	8.27	17.60	10.6	51.8
U. H. 4	8.74	15.12	...	30.5
U. B. 1	12.47	15.60	10.5	23.8
U. B. 3	8.42	11.01	8.3	21.1
Honokaa U. H. 1	9.13	....	...	....
Honokaa U. H. 2	14.43	....	...	....
U. D. 1	7.31	9.56	7.8	11.2
U. D. 6	7.55	12.04	9.5	12.4
U. D. 7	7.86	12.25	12.2	21.3
U. D. 9	11.20	14.22	11.4	12.8
U. D. 10	17.39	21.27	9.6	83.9
U. D. 11	12.31	20.17	14.0	49.7
U. D. 12	17.25	16.39	12.4	13.7
U. D. 13	10.22	10.95	13.6	10.5
U. D. 14	25.25	46.77	22.2	48.7
U. D. 18	10.13	20.97	11.3	27.2
U. D. 19	18.58	16.19	9.5	18.5
U. D. 20	10.17	17.41	12.4	11.6
U. D. 21	26.28	21.92	10.6	36.3
U. D. 22	....	73.11	...	15.2
U. D. 23	9.02	22.32	16.7	13.5
U. D. 25	8.77	16.23	12.9	11.8
U. D. 26	10.21	15.93	11.2	13.7
U. D. 28	12.49	24.00	...	22.8
U. D. 30	10.58	15.14	29.8	24.9
U. D. 31	27.38	28.05	23.6	27.5
U. D. 32	10.13	13.31	...	14.2
U. D. 33	14.74	14.47	15.6	18.7
U. D. 34	14.27	13.21	19.7	16.7
U. D. 35	12.42	13.00	10.3	43.4
U. D. 36	13.17	16.49	9.6	19.6
U. D. 37	15.73	12.41	14.7	12.4
U. D. 38	28.97	20.80	17.4	75.8
U. D. 39	7.56	9.27	16.7	12.9
U. D. 40	14.51	23.45	11.5	18.0
U. D. 41	13.86	16.63	17.3	30.2
U. D. 42	9.58	10.54	13.1	11.3
U. D. 47	8.64	19.60	...	28.9
U. D. 49	9.21	52.92	...	115.8
U. D. 50	9.34	12.73	...	12.2
U. D. 51	9.93	19.15	...	15.3
U. D. 52	12.12	19.31	20.3	14.0
U. D. 53	16.39	32.72	15.4	39.8
U. D. 55	12.82	46.58	...	40.6
U. D. 56	10.95	13.00	14.9	13.6
U. D. 57	16.03	50.20	51.3	45.9
U. D. 58	14.71	17.30	12.0	15.5
U. D. 60	9.50	18.83	14.5	18.9

U. D. 61	11.06	15.73	18.8	14.2
U. D. 62	10.16	21.41	...	27.2
U. D. 64	10.12	28.28	18.8	40.6
U. D. 65	9.88	15.26	...	19.3
U. D. 66	8.22	15.24	10.5	13.5
U. D. 67	13.11	14.44	...	15.6
U. D. 68	9.00	20.97	16.1	20.7
U. D. 69	11.88	154.48	28.7	18.5
U. D. 70	9.79	16.98	13.8	17.1
U. D. 71	11.33	16.82	14.9	30.6
U. D. 73	12.02	12.35	12.4	11.0
U. D. 75	11.40	20.79	13.3	14.7
U. D. 76	10.88	8.97	10.1	9.3
U. D. 78	9.74	18.71	...	16.7
U. D. 79	8.90	17.37	16.4	11.1
U. D. 80	9.80	18.93	...	11.0
U. D. 81	10.56	10.91	11.9	15.9
U. D. 82	31.69	10.24	9.6	11.1
U. D. 83	9.12	10.55	9.0	13.3
U. D. 85	14.02	15.78	11.6	16.4
U. D. 86	9.53	14.35	11.1	13.8
U. D. 88	8.53	14.92	10.8	18.7
U. D. 90	10.73	111.53	14.3	32.4
U. D. 91	10.57	13.39	14.2	18.3
U. D. 92	8.14	36.78	13.5	14.5
U. D. 94	25.24	10.75	32.0	17.7
U. D. 95	20.11	28.62	...	11.1
U. D. 96	13.10	16.24	...	18.4
U. D. 97	13.35	11.85	10.7	17.1
U. D. 100	10.44	14.03	11.8	16.2
U. D. 101	18.53	16.96	18.9	29.5
U. D. 102	21.57	23.89	37.2	28.4
U. D. 103	8.45	14.13	...	15.3
U. D. 104	8.98	13.35	10.8	14.2
U. D. 105	9.88	49.17	14.8	35.3
U. D. 106	10.23	13.41	15.7	12.6
U. D. 107	28.42	23.00	...	42.6
U. D. 108	10.44	15.21	11.2	15.8
U. D. 110	9.18	11.21	13.2	18.2
H 109	7.57	....	...	....
Uba	....	....	...	25.2
Striped Tip	....	....	...	12.3
Striped Tip	....	....	...	12.4
Striped Tip	....	....	...	9.8

MAKIKI PLOTS, FIELD 5, UBA AND HONOMU SEEDLINGS, AGE 18 MONTHS, HARVESTED IN FEBRUARY, 1926

Location	Seedling No.	Total Stalks	Injured	Total Weight, Lbs.	Length of Line	Lbs. per Foot	T. C. P. A. (Gross Area)	Q. R.	T. S. P. A. (Gross Area)	Remarks (Notes taken in the field)
							(With correction for outside lines)			
	U. H. 1	170	14	387	25′	15.5	54.02	6.88	7.85	Slight damage by rats and borers. Seed taken in 1925.
	U. H. 2	212	6	507	25′	20.3	70.74	7.76	9.12	Not very uniform.
Outside line	U. H. 3	289	0	699	25′	28.0	78.10	8.27	9.44	Clean cane.
Outside line	U. H. 4	141	0	413	25′	16.5	....	8.74	...	Uniform clean cane. Seed taken in 1925.
	U. B. 1	187	6	496	25′	19.8	69.00	12.47	5.53	Damaged by rats.
	U. B. 3	142	142	230	25′	9.2	32.06	8.42	3.81	All damaged by rats.
	Honomu 1	220	10	767	50′	15.3	53.32	9.73	5.59	Fairly uniform cane. Slight rat damage.
	Honomu 2	391	42	964	50′	19.3	67.26	9.25	7.27	Fairly uniform cane. Slight rat damage.
	Honomu 8	212	16	841	50′	16.8	58.54	8.10	7.23	Good uniform and clean cane.
Outside	Honokaa U. H. 1	...	..	731	35′	20.9	51.0	9.13	5.59	Very large number of very small stalks. Not a commercial cane.
Outside	Honokaa U. H. 2	156	2	385	32′	12.0	41.82	14.43	2.90	Fairly uniform. Slight rat damage.
Outside	H 109	89	11	453	18′	25.2	70.20	7.91	8.80	Some rat damage.
Outside	H 109	44	0	371	15′	24.7	60.30	7.23	8.33	Clean cane.
Outside	U. D. 6	168	7	446	20′	22.3	54.4	7.55	7.20	Fairly uniform and clean cane.
Outside	U. D. 7	207	5	490	20′	24.5	59.8	7.86	7.60	Fair cane. Slight borer damage.
	U. D. 9	154	0	371	20′	18.6	64.82	11.20	5.79	Fair.
	U. D. 10	158	42	411	20′	20.6	71.78	17.39	4.13	Uneven, staggered, broken. Not a commercial cane.
	U. D. 11	136	2	241	20′	12.1	42.17	12.31	3.43	Poor, very uneven and staggered. Slight rat damage. Not a commercial cane.
	U. D. 12	193	3	236	20′	11.8	41.12	17.25	2.38	Very small stalks, staggered. Not a commercial cane.
	U. D. 13	169	3	427	20′	21.4	74.58	10.22	7.30*	Node gall. Uneven. Not a commercial cane.

	U. D. 14.....	290	29	496	20′	24.8	86.42	25.25	3.42*	Very staggered and uneven. Slight node gall. Rats and borers. Not a commercial cane.
	U. D. 18.....	138	17	286	20′	14.3	49.82	10.13	4.92*	Staggered, uneven. Rats, borer. Slight node gall.
	U. D. 19.....	254	33	313	20′	15.7	54.71	18.58	2.94	Very poor type of cane. Staggered, uneven. Not a commercial cane.
	U. D. 20.....	186	3	425	20′	21.3	74.22	10.17	7.30*	Uniform, clean cane. Very slight node gall.
	U. D. 21.....	168	8	485	20′	24.3	84.34	26.28	3.21	Fair cane.
	U. D. 22.....	0	0	0		0	0	0	0	No cane on the ground. Shaded out. Seed taken in 1925?
	U. D. 23.....	203	2	453	20′	22.7	79.10	9.02	8.77	Fairly even and clean cane.
Outside.....	U. D. 25.....	145	1	553	20′	27.7	77.2	8.77	8.81*	Node gall—otherwise good cane.
Outside.....	U. D. 26.....	173	1	398	20′	19.9	55.4	10.21	5.43	Fairly even and clean.
Outside.....	U. D. 28.....	123	0	422	20′	21.1	51.5	12.49	4.12*	Node gall. Fair cane.
Outside.....	U. D. 30.....	175	8	714	20′	35.7	87.1	10.58	8.23*	Fairly clean and uniform. Node gall.
	U. D. 31.....	149	5	278	20′	13.9	48.44	27.38	1.77	Small stalks and staggered. Not a commercial cane.
	U. D. 32.....	79	5	259	20′	13.0	45.30	10.13	4.47*	Poor. Node gall. Not a commercial cane.
	U. D. 33.....	138	0	443	20′	22.2	77.36	14.74	5.25	Fair. Slightly uneven and staggered.
	U. D. 34.....	137	15	367	20′	18.4	64.12	14.27	4.49	Fair. Uneven and staggered.
	U. D. 35.....	151	6	552	20′	27.6	96.18	12.42	7.74*	Slight node gall. Uneven, slight borer.
	U. D. 36.....	141	2	472	20′	23.6	82.24	13.17	6.24	Fair. Slight rat damage.
	U. D. 37.....	173	13	368	20′	18.4	64.12	15.73	4.08	Fairly clean cane. Some broken.
	U. D. 38.....	52	10	155	20′	7.8	27.18	28.97	0.94	Poor. Slight rat damage. Not a commercial cane.
	U. D. 39.....	157	1	369	20′	18.5	64.47	7.56	8.53	Fairly uniform and clean cane.
	U. D. 40.....	139	4	482	20′	24.1	83.98	14.51	5.79	Fairly clean cane.
	U. D. 41.....	107	12	309	20′	15.5	54.02	13.86	3.90	Fair.
	U. D. 42.....	168	1	497	20′	24.9	86.77	9.57	9.07	Fairly uniform and clean cane.
Outside.....	U. D. 47.....	0	0	0		0	0	8.64	0*	Very bad node gall.
Outside.....	U. D. 49.....	160	1	211	20′	10.6	29.50	9.21	3.21	Poor. Not uniform. Not a commercial cane.
Outside.....	U. D. 50.....	31	0	179	20′	9.0	....	9.34	...	Large stalks. Good cane. Seed taken in 1925.
Outside.....	U. D. 51.....	112	8	366	20′	18.3	63.77	9.93	6.42	Uniform and clean.

* Node gall.

Location	Seedling No.	Total Stalks.....	Injured.....	Total Weight, Lbs.	Length of Line....	Lbs. per Foot.....	T. C. P. A. (Gross Area).....	Q. R.....	T. S. P. A. (Gross Area).....	Remarks (Notes taken in the field)
						(With correction for outside lines)				
	U. D. 52.....	138	10	497	20′	24.9	86.77	12.12	7.16	Small stalks. Staggered.
	U. D. 53.....	129	19	338	20′	16.9	58.90	16.39	3.59	Small stalks. Staggered and broken. Not a commercial cane.
	U. D. 55.....	146	6	358	20′	17.9	62.38	12.82	4.86	Fair.
	U. D. 56.....	116	17	341	20′	17.1	59.59	10.95	5.44	Fair.
	U. D. 57.....	166	8	629	20′	31.5	109.77	16.03	6.85	Fairly even and clean cane.
	U. D. 58.....	60	0	244	20′	12.2	....	14.71	...	Uniform cane and fairly clean. Seed taken in 1925.
	U. D. 60.....	130	0	312	20′	15 6	54.36	9.50	5.72	Fair.
	U. D. 61.....	96	7	279	20′	14.0	48.78	11.06	4.41	Fair.
	U. D. 62.....	101	1	440	20′	22.0	....	10.16	...	Good uniform, clean cane. Seed taken in 1925.
	U. D. 64.....	118	2	408	20′	20.4	71.09	10.12	7.02	Fair.
	U. D. 65.....	29	0	116	20′	5.8	....	9.88	...	Uniform and clean cane. Shaded in. Seed taken in 1925.
	U. D. 66.....	120	0	403	20′	20.2	70.39	8.22	8.56	Small stalks. Clean cane.
Outside line...	U. D. 67.....	27	...	36	20′	1.8	6.27	13.11	0.48*	Very bad node gall.
Outside line...	U. D. 68.....	186	16	411	20′	20.6	57.4	9.00	6.38	Small stalks. Large number of lalas. Not a commercial cane.
Outside line...	U. D. 69.....	175	20	312	20′	15.6	38.1	11.88	3.21	Small stalks. Fair.
Outside line...	U. D. 70.....	90	5	554	20′	27.7	67.6	9.79	6.90	Fairly uniform and clean. Slight borer.
	U. D. 71.....	173	6	421	20′	21.1	73.53	11.33	6.49	Uneven and staggered.
	U. D. 73.....	229	0	341	20′	17.1	59.59	12.02	4.96	Small and staggered. Fair.
	U. D. 75.....	216	6	649	20′	32.5	113.26	11.40	9.94	Fairly uniform and clean cane.
	U. D. 76.....	315	8	334	20′	16.7	58.20	10.88	5.35	Small and uneven. Rats and borers. Not a commercial cane.
	U. D. 78.....	44	0	148	20′	7.4	....	9.74	...	Fairly uniform. Seed taken in 1925.
	U. D. 79.....	167	8	503	20′	25.2	87.82	8.90	9.87	Fairly uniform and clean.

	U. D. 80.....	148	6	395	20′	19.8	69.00	9.80	7.04	Fair. Small stalks and staggered.
	U. D. 81.....	178	4	430	20′	21.5	74.92	10.56	7.09	Small and uneven. Not a commercial cane.
	U. D. 82.....	131	18	252	20′	12.6	43.91	31.69	1.39	Poor. Small stalks. Rat eaten. Not a commercial cane.
	U. D. 83.....	39	1	150	20′	7.5	26.14	9.12	2.87	Fair. Straight cane.
	U. D. 85.....	96	0	250	20′	12.5	43.56	14.02	3.11	Small uneven stalks. Staggered. Not a commercial cane.
	U. D. 86.....	151	0	339	20′	17.0	59.24	9.53	6.22	Uneven. Fair.
Outside line...	U. D. 88.....	211	2	611	20′	30.6	84.6	8.53	10.00	Slight node gall. Large number of fairly clean, uniform stalks.
Outside line...	U. D. 90.....	190	4	357	20′	17.9	49.9	10.73	4.65	Small and uneven. Staggered. Not a commercial cane.
Outside line...	U. D. 91.....	201	6	415	20′	20.8	50.80	10.57	4.80	Small and staggered.
Outside line...	U. D. 92.....	156	4	564	20′	28.2	68.80	8.14	8.45	Uniform. Fairly clean.
	U. D. 94.....	168	38	395	20′	19.8	69.00	25.24	2.73	Small and staggered.
	U. D. 95.....	57	25	76	20′	3.8	13.24	20.11	0.66	Small. Much dead cane. Shaded in. Not a commercial cane.
	U. D. 96.....	106	10	380	20′	19.0	66.21	13.10	5.05	Fair.
	U. D. 97.....	178	5	430	20′	21.5	74.92	13.35	5.61	Fair.
	U. D. 100.....	144	2	619	20′	31.0	108.03	10.44	10.35	Very good uniform and clean cane.
	U. D. 101.....	196	12	364	20′	18.2	63.42	18.53	3.42	Small and uneven.
	U. D. 102	126	2	284	20′	14.2	49.49	21.57	2.29	Uneven and staggered. Not a commercial cane.
	U. D. 103.....	63	3	322	20′	16.1	56.10	8.45	6.64	Fair.
	U. D. 104.....	131	15	415	20′	20.8	72.48	8.98	8.07	Fairly clean cane.
	U. D. 105.....	126	5	431	20′	21.6	75.27	9.88	7.62	Fair.
	U. D. 106.....	132	10	561	20′	28.1	97.92	10.23	9.57	Fairly uniform and clean.
	U. D. 107.....	106	50	53	20′	2.7	9.41	28.42	0.33	Very small stalks. Not a commercial cane.
Outside line...	U. D. 108.....	82	2	161	20′	8.1	....	10.44	...	Poor. Very small spindly stalks. Not a commercial cane.
Outside line...	U. D. 110.....	98	2	514	20′	25.7	71.70	9.18	7.81	Fairly uniform.
Field 10.....	U. D. 1.....	171	3	545	25′	21.8	60.80	7.22	8.42	Clean cane.
Field 10.....	U. D. 1.....	...	..	...	..	...	....	7.39	...	Sample only.

[1] Node gall.

The "net yields" were deducted by 20% in order to make the figures more nearly comparable to plantation conditions. Also the outside lines were further deducted by 20% for mauka outside lines and 30% for makai ones. This makes a more even comparison among the seedlings.

An Explanation of the Decrease in Purity Between Clarified Juice and Syrup

By H. F. Bomonti

At the request of one of the factories, the writer investigated the decrease in purity between the clarified juice and syrup which was indicated by the laboratory figures.

The clarified juice purity at this factory represents the purity of all the juice entering the evaporator. Under these conditions there is only one thing which will cause a decrease in purity, that is, the inversion of sucrose.

If, however, there is a constant error in the analysis of the syrup sample, a decrease in purity can be secured.

In order to find out whether there was any inversion of sucrose, samples of both clarified juice and the diluted syrup were composited for a twenty-four hour period and analyzed for glucose and polarization. These composite samples were preserved with bichloride of mercury. By comparing the ratios of glucose to polarization of the clarified juice and syrup, any inversion of sucrose during this phase of the process would become apparent. A small increase in glucose will show a pronounced change in the ratio of glucose to polarization.

Glucose was determined by a volumetric method which is unusually simple and accurate. It is known as the Methylene Blue method and is fully outlined in *Facts About Sugar,* November, 1923. Several known mixtures of glucose and sucrose were tested by the method, giving extremely accurate results.

The following tabulation (Table I) gives the analyses of the composite samples for a two-week period, starting January 8:

TABLE I

	Clarified Juice					Syrup (diluted 1-5)					
Date..... 1926	pH.....	Pol.....	Pur.....	Gluc.....	Gluc. Pol.....	pH.....	Pol.....	Pur.....	Gluc.....	Gluc. Pol.....	Difference between clarified juice and syrup..
Jan. 8	7.3	10.98	85.79	.50	4.554	7.2	11.14	84.77	.53	4.758	—1.02
" 9	7.3	11.37	85.56	.52	4.573	7.4	11.29	85.27	.53	4.694	—0.29
" 11	7.4	11.56	86.08	.52	4.499	7.3	11.23	85.86	.51	4.542	—0.22
" 12	7.3	11.34	85.07	.54	4.762	7.25	11.29	85.19	.56	4.960	+0.12
" 13	7.3	11.34	84.95	.57	5.026	7.25	11.47	85.10	.58	5.057	+0.15
" 14	7.5	11.78	86.18	.54	4.584	7.4	11.16	85.54	.52	4.414	—0.64
" 15	7.5	12.01	87.28	.50	4.164	7.5	11.02	86.59	.45	4.084	—0.69
" 16	7.45	11.76	86.47	.51	4.337	7.36	11.16	86.09	.50	4.480	—0.38
" 18	7.57	12.12	87.57	.50	4.126	7.5	11.63	87.51	.49	4.213	—0.06
" 19	7.57	11.92	87.58	.49	4.111	7.5	11.67	86.95	.49	4.200	—0.63
" 20	7.6	11.85	87.71	.49	4.135	7.6	11.80	87.61	.49	4.153	—0.10
" 21	7.6	11.46	86.82	.54	4.712	7.6	11.66	86.99	.55	4.717	+0.17
Average	7.4	11.62	86.42	.52	4.475	7.4	11.38	86.12	.52	4.57	—0.30

Inspection of the above tabulation shows that the average increase in the ratio of glucose to polarization in the diluted syrup sample is small, amounting to about .01 per cent glucose. In no case does the increase in glucose account for the decrease in purity where the decrease is large. The average figure for two weeks shows a decrease in purity of 0.30, while the increase in glucose only accounts for about one-fourth of this amount.

The pH values of the clarified juice and syrup samples were fairly uniform, as indicated by the figures given in the tabulation. Hourly samples for pH show some variation, but they are not low enough to be a serious factor even under the existing operating conditions.

The analyses of the syrup samples in Table I were made by diluting the syrup (1:4 dilution) with tap water. An analysis of this tap water showed that there was .05 per cent inorganic matter in the water, which affected the Brix about 0.10 per cent.

The salt content of the tap water might easily vary from time to time, which explains the variations of the decrease in purity which occurred at this factory.

By substituting distilled water for tap water when diluting syrup samples, a slight increase in purity of the syrup was secured. In Table II are tabulated the purities of clarified juice and syrup for seven weeks during which tap water was used and eleven weeks during which distilled water was used.

TABLE II

Weekly Figures Showing the Purities of Clarified Juice and Syrup

	Clarified Juice			Syrup				
Week of	Brix	Pol.	Purity	Brix	Pol.	Purity	Diff.	
1925								
Dec. 5	13.45	11.14	82.83	69.43	57.11	82.3	—0.53	Syrup diluted with tap water
" 12	13.72	11.42	83.24	69.51	57.70	83.01	—0.23	
" 19	13.95	11.77	84.37	66.04	55.56	84.13	—0.24	
" 26	12.96	10.68	82.41	65.98	54.38	82.42	+0.01	
1926								
Jan. 2	13.85	11.76	84.91	67.98	57.71	84.90	—0.01	
" 9	13.39	11.47	85.66	66.98	56.98	85.07	—0.59	
" 16	13.52	11.63	86.02	65.53	56.12	85.64	—0.36	
Average	13.55	11.41	84.21	67.35	56.51	84.91	—0.30	Average decrease in purity 0.30
1926								
Jan. 23	12.38	10.73	86.67	66.92	58.30	87.12	+0.45	Syrup diluted with distilled water
" 30	13.70	11.94	87.15	66.37	58.10	87.54	+0.39	
Feb. 6	14.33	12.61	88.00	67.10	59.13	88.12	+0.12	
" 13	14.21	12.47	87.76	65.30	57.28	87.72	—0.04	
" 20	14.62	12.85	87.89	67.14	58.81	87.59	—0.30	
" 27	14.64	12.92	88.25	65.42	57.57	88.00	—0.25	

Mar. 6...	15.07	13.33	88.45	68.60	60.75	88.56	+0.11
" 13...	14.74	12.95	87.86	67.98	59.81	87.98	+0.12
" 20...	15.21	13.38	87.97	67.01	58.86	87.84	—0.13
" 27...	15.13	13.19	87.18	67.63	58.91	87.11	—0.07
Apr. 3...	14.26	12.37	86.75	67.23	58.46	86.96	+0.21
Average ..	14.39	12.61	87.63	66.97	58.73	87.70	+0.7

Average for 11 weeks shows an increase of .07 between clarified and syrup.

The above tabulation shows that with the exception of two weeks (ending February 20 and February 27, 1926), the purity of the syrup is very close to the purity of the clarified juice when using distilled water. The average purity of the syrup for the eleven weeks is .07 higher than the purity of the clarified juice.

The decrease in purity during the two weeks mentioned was due to an error in the correction at one point on the Brix hydrometer used during that period.

Conclusion

This investigation has shown that it is essential to use water which is free from dissolved solids in diluting syrup, massecuites, and molasses samples.

Where distilled water is not available, the water used should be tested for dissolved solids, since relatively small amounts will reduce the purity of the sample.

Oxya Velox as a Grasshopper Cane Pest in Hawaii

By O. H. Swezey

This grasshopper, *Oxya velox* (Fabr.), occurs from Japan and China to India, Java and Australia. It reached Hawaii quite a number of years ago, for it was abundant on Kauai and Oahu at the time the Orthoptera of the Fauna Hawaiiensis, by Dr. Perkins, was published in 1899. Dr. Perkins states that in 1897 it had not yet spread to the other islands of the group. The only record of it on Maui, so far, is a small colony in a grassy region in a valley in the makai part of Haiku, found by the writer, August 24, 1918. On Hawaii, the only record is by Mr. Williams in a cane field at Hilo Sugar Company, mauka of Wainaku, September 19, 1925. Just why it has spread so slowly on the other islands is not readily explained. Perhaps it is only in recent years that a few have reached Maui and Hawaii from Honolulu, and have not yet had time to increase and become generally spread.

For the past twenty years, on Kauai and Oahu, this grasshopper has been known to feed on cane to some extent at the edges of fields or along grassy roadsides where they have gone from the grass onto the cane. Young nut grass is a favorite food of the young grasshoppers and it is often in nut grass regions

that they have increased to such an extent as to do noticeable injury on the adjoining cane. At the Experiment Station, some of these grasshoppers are always to be found in the portion of the grounds where nut grass prevails, and often a few, or many, stools of cane have a very ragged appearance from the feeding of the grasshoppers on the leaves.

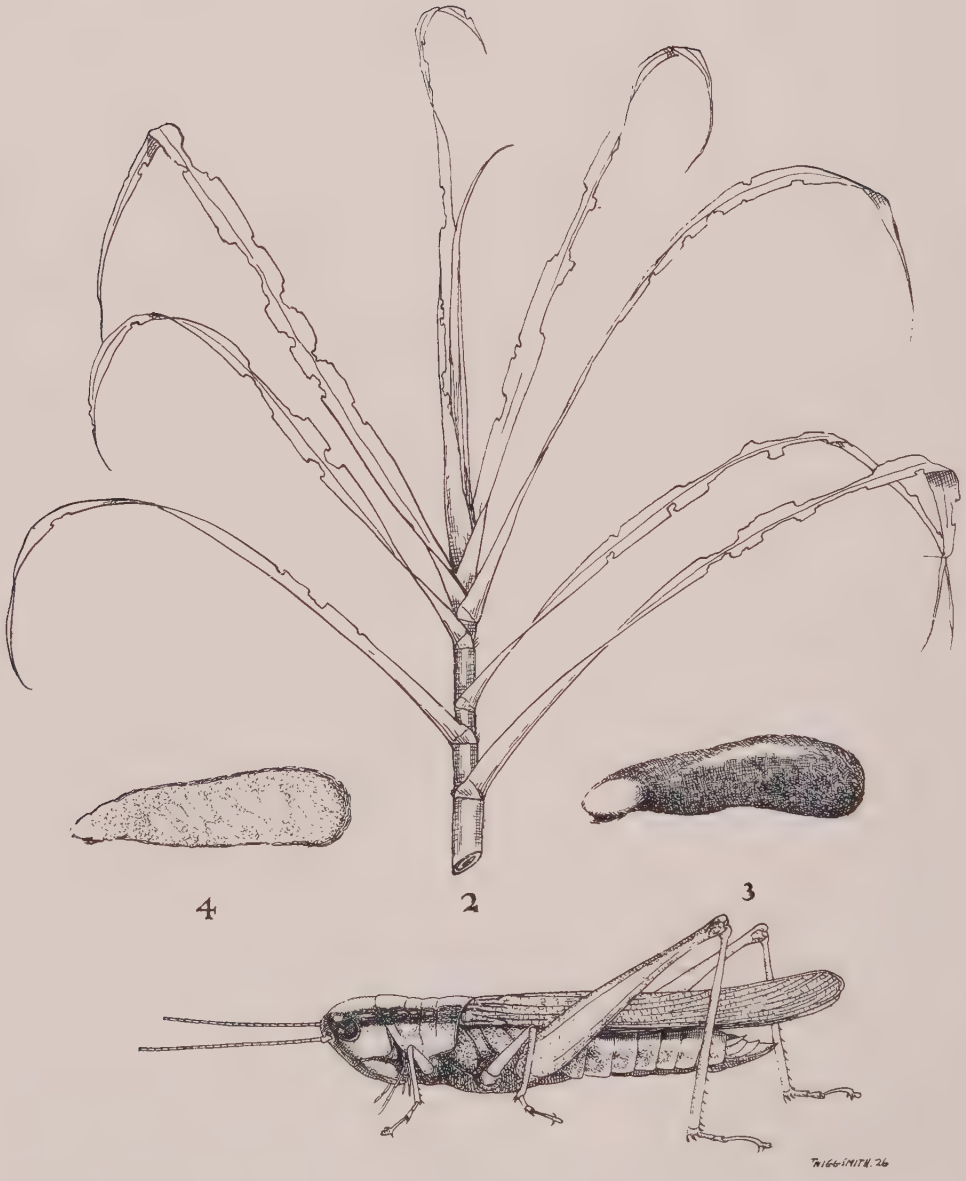
In February, 1924, several acres in a field at Waimanalo had the cane badly eaten, so that all of the upper leaves were very ragged.

For several years past, a colony of grasshoppers has persisted on the grassy roadsides between Fields 10A and 10B, at Ewa Plantation Company, especially toward the eastern end of this road, and the cane at the corner of the field has, at intervals, been noticed to be more or less injured by them. Apparently there has been an increase in this colony, for last year the cane for a wide extent in these fields was considerably eaten by the grasshoppers. On the entomologists' attention being called to it, on their first visit October 30, 1925, many large grasshoppers, chiefly nearly full-grown nymphs and a few adults, were feeding on the cane on both sides of the road and extending for several hundred yards farther into the fields. For a considerable area, most of the upper leaves were ragged from the eating of the grasshoppers and sometimes as many as half a dozen were seen eating on the same leaf.

Numerous small young grasshoppers were feeding on the nut grass of the roadsides and also in the fields, which were very heavily infested with nut grass. Apparently the presence of the nut grass has been an attraction to the grasshoppers as food for the young, from which they have gone up onto the cane leaves as they became half-grown or more. None of the little grasshoppers were observed feeding on the cane, but a swarm of them was raised from the nut grass in walking through it.

When visited a month later, most of the grasshoppers were found to have become matured and many were mating, mostly along the road. After considerable search, a batch of eggs was found. It was slightly below the surface of the soil amongst the nut grass plants. At subsequent visits, more of these egg-masses were found in the banks of nut grass at the edge of the cane field. Visits were made to the place at frequent intervals for a few months and it was found that the number of grasshoppers on the cane diminished and that the newly grown leaves were less eaten and, thus, the recovery of the cane was accomplished, though there must have been some check for a time when the grasshoppers were most numerous on the cane. If the grasshoppers make their appearance quite generally in the nut grass of these fields, when growth starts after the next harvesting, it will be a good opportunity to try the value of poisoning while the cane is yet small enough to allow the operation of spraying or dusting machinery in the field.

Another case of injury by this grasshopper was in cane along a railway in a field just a little north of Hauula on the windward side of Oahu. This place was visited by the entomologists November 9, 1925. At this place there had been considerable grass along the railway. It had recently been cleaned up. Apparently the grasshoppers that had previously been feeding on the grass had



Oxya velox

1. Adult female.
2. Cane shoot eaten by grasshopper.
3. Egg mass.
4. Egg mass sectioned, showing eggs.

gone to the cane and, in several places, their work was conspicuous, though not serious.

Another considerable outbreak of this grasshopper occurred at Honolulu Plantation Company. Attention having been called to it, the place was visited February 19, 1926. A field in Halawa Valley having nut grass along a railway line traversing the field, showed considerable ragged leaves where the grasshoppers had gone to the cane from the nut grass. The injury was chiefly along the edge, not extending inside much, but a few stools were observed at the edge of the field that had most of the leaves stripped to the midribs. This region extended for nearly half a mile along the railroad. As at Ewa Plantation Company, the small young grasshoppers were numerous on the nut grass while the larger nymphs and adults were feeding on the cane leaves.

In November, as it appeared that this grasshopper had increased to considerable importance, and as its life history was very imperfectly known, breeding cages were started at the Experiment Station and maintained for several months to determine definitely the life cycle, etc. The various stages have been pretty well worked out. Single pairs were isolated in separate cages for oviposition and as many as 3 egg-batches per female were obtained at intervals of about a week. Each of these contained about 20 eggs cemented together with a light brownish substance and placed about half an inch to an inch into the soil of the cage used. The records of hatching of quite a number of egg-batches gave a nearly uniform period of 6 weeks. The young grasshoppers grew to maturity in 6 to 10 weeks, there being considerable variation in the time taken. Molting took place at irregular intervals, usually about 10 to 16 days, but sometimes up to 24 days. There were 7 molts, including the one at the time of issuing from the egg, and the final molt when the insects became mature.

Several batches of young were carried through to maturity and then kept until their final death. There was considerable range in this, and no doubt they might have lived longer in the field. In the cages, adults lived from 8 to 12 weeks.

A summary of the life cycle follows:

Egg stage—6 weeks.
Nymph stages—6 to 10 weeks.
Adults lived—8 to 12 weeks.

Thus the total life cycle from oviposition to death of adult grasshopper is 20 to 28 weeks and the length of the feeding period is 14 to 22 weeks. From these data, it is evident that two broods per year are possible and that the 3 to 5 months feeding period makes it possible for them to eat a great deal of grass or cane during a lifetime. Further investigation of the habits and distribution and injury by this pest will be carried on.

The Flowering of Sugar Cane in Hawaii

By Clyde C. Barnum

The breeder of sugar cane is continually striving to obtain, by crossing existing varieties, new seedlings possessing high sugar yielding qualities together with an inherent resistance to certain specified cane diseases. Desirable seedlings must be hardy, must have very good ratooning qualities which lower the cost of production through less frequent planting. Any quality in a new seedling which will decrease the cost of production is essential. In the selection of parent canes for these crosses the plan has frequently been to choose one parent with a very high sugar yield, although having more or less susceptibility to the locally existing cane diseases, and cross this with some well known highly disease-resistant variety. In order to intelligently carry on such work and secure controlled crossing of such desirable characters methods have been devised and certain improvements in the technique have been developed in view of the studies made on sugar cane flowers. Pollen-producing tassels of the desired variety are suspended over the tassels which are to be pollinated and the supposedly cross-fertilized tassel is, after ripening, planted in order to germinate the matured seed. The studies here reported are the observations made during two tasseling seasons in Hawaii and consequently might not apply in other localities under different weather conditions.

In the tasseling season of 1924 the writer observed that certain cane varieties produced apparently viable pollen, other varieties produced little or no pollen; that pollen production of cane varieties was apparently associated with the color of the anthers at or soon after emergence of the individual flowers from the floral envelopes, and that there was a very definite periodicity of flower opening associated with individual cane varieties. The observations made during the tasseling season of 1924 have been more closely followed up during the 1925 season and have materially substantiated the findings of the previous season.

In the literature on the subject of sugar cane flower study Brandes (1)* and Calvino (2) both state that the sugar cane flowers open in the early morning hours. At what hour in the morning the several cane varieties opened new flowers in Hawaii was not definitely known for several cane varieties previous to 1924. In the work of cross fertilizing cane varieties a knowledge of the hour during the early morning when the flowers of each commercial cane variety are opened is of great importance. The period of receptivity of certain varieties may be so late in the day as to preclude the fertilization of the flowers by pollen from earlier flowering varieties unless certain precautions be taken. Certain varieties of cane known to be self-sterile can only be used as female flowers. This work is intended to clear up these points and establish certain definite relations which will be useful in further cane breeding operations.

* Note: Numbers in parenthesis refer to "Literature Cited."

Methods Employed in Keeping Tassels Under Observation

The method of Verret, Kutsunai and others (3) for the maintenance of sugar cane tassels in a healthful growing condition in weak aqueous solutions of sulfurous acid was used throughout this work. Cane stalks on which the tassel was just emerging from the sheath were cut in the field and brought into the laboratory with the cut ends under water. These stalks were then placed with the cut ends immersed in sulfurous acid of the correct concentration in individual glass containers. These solutions were changed daily throughout these studies. Tassels so maintained have been kept in a vigorous growing condition for several weeks. The tassels pushed out of the sheath and spread out the branches and spikelets, bearing their numerous flowers, just as growing tassels on the field-grown plants did. During the two seasons, observations have been made on cut tassels in the laboratory with adequate ventilation at all times, as well as out of doors, fully exposed to the prevailing weather conditions. In the absence of rain water on the flowers and tassels the diurnal emergence of new flowers on cut stalks has been found to be identical in tassels kept either inside or outside the building. Rain upon tassels had a deterring effect on anther dehiscence as will be shown later in this paper. For continued observation of individual tassels, only very young tassels were selected and observations begun at the time of emergence of the first flowers. As is usually the case the first flowers to emerge appeared near the tip or distal end of the tassel. These flowers were daily clipped from the spikelets with small shears, or the flowering spikelet was cut back far enough to remove a large number of flowers quickly. The clipping of opened flowers on all tassels was usually done in the late afternoon. Any flowers found open during the following night were, therefore, those flowers which had opened after 4 p. m. of the previous day.

Determination of the Period of Diurnal Flowering of D 1135 Tassels

The initial work on this problem was instituted on November 24 and November 25, 1924, in connection with the problem of determining the hour, or hours, when the most viable pollen could be obtained for artificial germination during a 24-hour period. Observations were made hourly during this period from noon of November 24 to the following noon. For this work 7 tassels of D 1135 cane were maintained in sulfurous acid solution in a sunny room in the laboratory. No light reached these tassels during the night except at short intervals when observations were made, when pollen was taken or when specimen spikelets were taken for microscopic observation. Unfortunately, in view of later work, the initial flowers of six of the tassels under observation had already opened before this test was begun. The tassels were vigorously shaken at the beginning of each hour of the 24-hour test over the three opened Petri dish germinators prepared for that hour and microscopic examination was made later for germinated pollen grains on the 72 plates so prepared. The first exposed plates contained fairly large numbers of wrinkled pollen grains, which failed to germinate, indicating that this pollen had been exposed to dry air several hours and that it had come from the flowers which had opened early on the morning of November 24. Since

this particular study was more closely associated with pollen germination than with flower emergence the hourly observations of flower activities were not as carefully recorded at this time as they were later on when the full significance of flower opening was realized. The fall of pollen decreased regularly during the first 16 hours, but at 5 a. m. the casts of pollen on the Petri dishes were greatly increased in numbers of pollen grains and during the next 5 hours they were distinctly heavy. This heavy cast of pollen followed the heavy flowering which was recorded that night as having occurred and continuing at 3 a. m. An earlier observation recorded at 10 p. m. indicated that flowers were enlarging rapidly within the glumes and by 12 midnight newly opened flowers were first observed on the 7 tassels. The heaviest flowering occurred between midnight and 3 a. m.

On the same date a somewhat similar test was made to determine the period of dehiscence of pollen from a single fresh tassel which had opened approximately one-third of its flowers previous to the beginning of the test. In this test, however, the tassel was not disturbed in the least during the 24-hour period. Each hour a Petri dish was opened and allowed to remain open under the tassel for that interval so that any falling grains of pollen might be caught on the plate surface. The tassel was placed in an upright position in a closed room. Each successive plate was placed in the same spot at each change of dishes. No appreciable numbers of pollen grains were found on any plates exposed previous to 3 a. m., although 4 to 6 grains were found on the 1 and 2 a. m. plates. At 4, 5, 6, 7 and 8 a. m. heavy casts of pollen occurred which germinated extremely well. This test indicated that anther dehiscence began on this particular night at 1 a. m. and that pollen grains were discharged in a viable condition for a period of 7 hours. The heaviest cast of pollen occurred between 3 and 6 a. m. Microscopic study of opening flowers revealed the fact that frequently pollen dehiscence occurred simultaneously with the opening and extrusion of the floral parts. This tendency would make self-fertilization very pronounced in this cane variety.

In support of this suggestion the observations made December 6, 1924, are very strong evidence. The 7 tassels of D 1135 which were under observation were trimmed free of all open flowers the previous afternoon. At midnight no flowers were open on any tassels in this group. At 12:15 a. m., December 6, a flower, in which the floral parts were well extended, was examined under the compound microscope; one anther sac was open and several grains were adhering to the stigmatic hairs. Careful observation indicated that at least one pollen grain had germinated on a stigmatic hair, and the pollen tube had penetrated the stigmatic surface sufficiently to resist gentle tension applied with a dissecting instrument, without rupture of the pollen tube. On 6 tassels heavy flowering had occurred at 1 a. m., and at 2 a. m. practically all well distended anthers were dehiscing turgid pollen grains freely.

Again on December 1, flowers were opening at midnight, yet little pollen was obtained. Very few anthers were open until 4 a. m. and the heavy cast of pollen came at 5 a. m. Self-pollination was observed by 5 a. m. on the stigmas of many flowers.

On these 7 tassels mentioned above, the few initial flowers had appeared on December 3, 1924, at midnight. At 12:30 a. m., December 4, counts were made

of open flowers on several tassels. On tassel No. 1, 30 flowers were open; on No. 4, 23 flowers were open and on No. 7 only 10 flowers appeared. At 2 a. m. the large number of flowers open on these three tassels precluded counting. After 3 a. m. further flower opening was not observed on certain spikelets under observation on which open-flower counts were made. Hourly pollen casts shaken directly into opened Petri dish germinators throughout the same night were heavy only at 1 and 2 a. m. Good germinations were obtained from these plates.

On the same tassels flowering began at midnight, December 5. At 1 a. m., December 6, 1924, pollen was cast freely. Heavy casts of turgid pollen grains were obtained from tassels Nos. 1, 5 and 7, hourly from 1 a. m. to 6 a. m., all of which yielded good germinations of pollen grains.

Again from the same 7 tassels cut December 2, 1924, on December 10, heavy casts of extremely viable pollen grains were obtained at 3:30, 4:30 and 5:30 a. m. On the 9 plates containing pollen obtained at these hours over 120 germinated pollen grains were counted. This would again point to these hours as the best period for obtaining viable pollen under laboratory conditions. No data are available for the earlier hours of the last mentioned study.

On December 11, 1924, a new set of ten D 1135 tassels cut that day and just beginning to flower were put in the outdoor air for a test. All open flowers were trimmed away. No flowers opened previous to midnight. At 1 a. m., December 12, 1924, the first flowers to open appeared on tassels Nos. 5 and 7. Anthers were open at this time on one tassel and not on the other. There were numerous open flowers on 7 of the 10 tassels at 2:20 a. m. No pollen was found on any stigmas at this time. At 3 a. m. flower opening was continued, anther sacs were open, but not dehiscing freely. At 4 a. m. nearly all anther sacs were open and were extruding pollen. Stigmas were almost invariably well covered with plump pollen grains. Pollen was falling freely from the now pendant anthers. Throughout the early morning hours of this test the relative humidity readings were 85 per cent or higher. At 95 per cent relative humidity, the pollen grains remained adhering closely together in the ruptured anthers and were not discharged. Under the microscope these grains appeared very turgid, had particularly moist surfaces and adhered closely to dissecting needles or other objects. Under conditions of lower humidity pollen grains were less adhesive and were more freely discharged from the anthers.

In order to watch the opening of individual flowers under the microscope, an electric light was placed with a flask of cold water interposed between the lamp and the microscope stage, so that the heat of the lamp would not influence the flower activity, and the emergence of new flowers on a horizontally placed living D 1135 tassel was closely watched. A flower was seen to fully open from the first sight of the tips of the floral parts to their full distension in 7 minutes, beginning at 12:17 a. m. and completed at 12:24 a. m., December 11, 1924. Fig. 1 shows a flower in the process of emerging from the floral envelope. Another flower was seen to open the glumes and distend the stigmas fully between 1 a. m. and 1:17 a. m., December 11, 1924. At 2:20 a. m. on over 20 flowers examined, the stigmas were the most prominent of distended floral parts and where the anther sacs could be seen at all they were split open, although no pollen was

Fig. 1. Fully developed flower of D 1135 cane, showing plainly three anthers; two stigmas and the two lodicules at the base of the flower. The ovary lies between the two lodicules. X 25.

Fig. 2. Emerging flower of D 1135 cane. The floral parts are just pushing out of the glumes. X 40.

observed on any stigmas. In Fig. 2 a fully distended D 1135 flower is shown dissected from the glumes. The anther dehiscence is just beginning on these anthers at the distal ends. With further studies on ten D 1135 tassels on December 18-19, 1924, flower opening did not occur until 2 a. m., December 19, 1924, and no pollen was cast until 5 a. m. when most of the anthers were found to be open and pollen was present on the stigmas of such flowers. At no time during the night was the relative humidity higher than 90 per cent and this only at 5 and 6 a. m.

On December 20, 1924, no observations having been made previously, flower opening was not observed until 5 a. m., while at 6 a. m. the splitting of anthers was just commencing. The first record of relative humidity taken that morning was 91 per cent at 4:30 a. m. This percentage remained constant until 8:30 when it fell to 80 per cent. At 6:37 a. m. pollen was found on the stigmatic hairs of these newly opened flowers indicating that dehiscence of pollen had begun.

On December 22, flower opening was in progress at 1:10 a. m. Flower opening ceased at 3 a. m. Humidity readings were relatively low during the early morning; at 12 midnight, the reading was 70 per cent and at 1 a. m., 67 per cent, the highest being 87 per cent at 1:30 a. m.

Throughout these studies in 1924 on the D 1135 tassels it was noted that heavy flowering of any single night was associated with fairly high relative humidity previous to and during the usual period of flower emergence. It was also very apparent on those nights when the humidity was very low that flower opening was distinctly retarded, as well as reduced in relative numbers of opening flowers. On five of the six nights on which flowering was observed throughout the night, flowers were open at 1 a. m.; on one night flowers did not appear until 2 a. m., but on these nights pollen could be obtained by 3 a. m. The heaviest observed casts of pollen occurred between 3 and 6 a. m. under these laboratory conditions.

Effect of Rain Upon Sugar Cane Flowering and Pollen Dehiscence During the Early Morning

Observations in the field and on tassels exposed near the laboratory to outside conditions on several rainy mornings pointed to a deterrent effect on pollen dehiscence induced by rainfall. An experiment was planned to prove this point. Four young D 1135 tassels cut December 6, 1924, were trimmed free of all open flowers on December 7 and put in a cloth cage which could be sprinkled regularly to maintain very high humidity within the cage. The four tassels were placed inside the cage with their cut ends in a bucket of fresh water. The cage and enclosed tassels were sprinkled with a garden hose at the start, 1 p. m., and at 6, 8 and 9 p. m., and again at 3:30 a. m. The water in the bucket was changed frequently during the test. The humidity of the outer air was very high throughout the night of December 7-8, 1924. Table 1 gives the relative humidity of the atmosphere of both the cage interior and exterior. The readings within the cage were taken from a wet-bulb hygrometer and the readings for the exterior were taken by means of a swing psychrometer.

TABLE 1

Relative Humidity and Dew Point Readings Showing Conditions Both Inside and Outside Moisture Cage in Yard at Experiment Station

Date 1924	Hour	Cage Interior Atmosphere Rel. Humidity (Percentage)	Cage Interior Atmosphere Dew Point (Degrees)	Exterior Atmosphere Rel. Humidity (Percentage)	Exterior Atmosphere Dew Point (Degrees)
Dec. 7	1 p. m.	62	68	68	67
" 7	6 p. m.	78	68	84	67
" 7	7 p. m.	91	69	88	67
" 7	8 p. m.	86	68	88	64.5
" 7	9 p. m.	86	68	90	65
" 7	10 p. m.	90	65	93	65
" 7	11 p. m.	85	62	90	62
" 7	12 p. m.	86	62	86	63.5
" 8	1 a. m.	86	64	88	65
" 8	2 a. m.	90	65	90	64
" 8	3 a. m.	90	65	90	65
" 8	4 a. m.	90	65	93	65
" 8	5 a. m.	90	64	95	63
" 8	6 a. m.	90	62	92	62.5

The first observed open flowers were found at 7 p. m. in the cage. At 1 a. m. more flowers were open on one of the tassels in the cage. At 3 a. m. numerous flowers were open in the cage, but of those flowers examined under the binocular only one bore anthers that were open. In this case the anther was split but no pollen had extruded from the narrow opening. No pollen was found on any stigmas. Again at 5 a. m. no pollen was found on stigmas, only a very few anthers were slightly cracked and no pollen was falling. Control tassels kept in the outside air but protected from rain behaved in exactly the same manner. Open flowers were found at 1 a. m. on these tassels and anther dehiscence did not occur until about 6 a. m. Examination of flowers in the cage at 9 a. m. showed many anthers still closed at that time. The very high humidity during the rainy night unquestionably checked anther dehiscence on the exposed tassels.

This experiment was repeated on December 9-10, 1924, using the same tassels in the cage as were used previously, together with 6 control tassels kept in the outer air. The latter were cut December 6. All were in good condition on December 9. All open flowers were trimmed off the tassels before 9 p. m., December 9, 1924. At 12:45 a. m. over 300 new flowers were counted on two tassels in the outer air. At 2 a. m. flowers were still opening and numerous anthers were dehiscing pollen. At 3 a. m. more open flowers were observed than before, anthers were still opening but pollen was not found on any stigmas. At 5 a. m. nearly all anthers were open on all observed flowers on the exposed tassels. Very little pollen was observed on any stigmas. These tassels were not shaken during these observations and as the anthers had opened after emergence from the glumes very little pollen had come in contact with the stigmas. The high humidity also contributed, no doubt, to the slow dehiscence of pollen. In the moist cages on the four tassels enclosed, flowering was in progress from midnight until 6 a. m. At that time no pollen was found on any stigmas observed under the microscope although frequently split anthers were found. This splitting of the anther sacs was attributed to the swelling of the maturing pollen grains within. Pollen grains would be immediately thrown out under drier atmospheric conditions. The anthers remained split open but not dehiscing the enclosed pollen even as late as 8 a. m., December 10, when the observations ended.

It might be a noteworthy observation that in D 1135 tassels under normal conditions the dehiscence of pollen at the time of flower emergence tends to insure self-fertilization at this particular time. On the other hand, when anther dehiscence is held in abeyance by sprinkling the tassels, self-fertilization is very much restricted, since the pollen grains falling from the pendant anthers seldom drop on receptive stigmas. Also when the humidity begins to decrease the relative humidity of the atmosphere may be so low by the time the pollen is extruded that the grains may become shriveled before reaching the stigmas. Especially so in case of bright drying sunlight with dry winds just after sunrise.

A similar test on retarding pollen dehiscence was made on D 1135 tassels the succeeding year. Twenty emerging tassels were obtained December 7, 1925, and placed, two in each of ten cages, with the cut ends immersed in daily renewed sulfurous acid solutions.

Five of the cages were wet from the top as well as on the sides during the early evening hours and again hourly after 3 a. m. throughout each day of the test. The other 5 cages were not intentionally sprinkled throughout the test. All open flowers were trimmed from these 20 tassels in the late afternoon of each day. On December 8 in three of the wet cages no open anthers could be found on the enclosed tassels at 3 p. m. In all the dry cages at this time all observed anthers were open and the pollen had been dehisced.

On December 9, which had been a very hot day, there were still approximately 40 per cent of the newly opened flowers having entirely closed anthers at 9 a. m. In the dry cages at the same hour 100 per cent of the open flowers had anthers fully dehisced. On December 10 at 8:30 a. m. no pollen could be found on the stigmas of the flowers which opened that morning in the moist cages, although a few anthers were slightly cracked open. At the same hour in the dry cages over 50 per cent of the anthers of the newly opened flowers were open. This was a very hot day with a strong breeze prevailing which made moisture conditions in the cloth cages difficult to maintain. At 11 a. m. over 50 per cent

of the anthers were still closed in the wet cages, while 100 per cent were open in the dry cages. These conditions remained fairly constant as late as 3 p. m. On December 11 at noon 50 per cent of the anthers were still closed in the wet cages on the day's open flowers. In the dry cages 100 per cent were open at the same hour. On December 12 careless watering induced identical conditions in both wet and dry cages.

The point seems to be very well established that the effect of water on the tassel actually inhibits the opening of the anthers for several hours after the flower opens. This fact points to a means of controlling crosses between strongly self-fertile cane varieties, in which case even reciprocal crosses could possibly be made on tassels which had been cut and placed under controlled conditions.

Comparative Study of Diurnal Flowering of Commercial Cane Varieties

Observed differences in the flowers of different cane varieties were noted early in these studies. The failure to obtain pollen casts of certain varieties indicated the non-dehiscence of pollen. On such varieties the most easily observed difference in such cases was in the anther coloring after emergence. On those varieties having anthers of an old rose or reddish color, pollen could be obtained. On those varieties having lemon-yellow anthers only, no dehiscence was observed nor could any pollen casts be obtained.

The varieties having perfect flowers, that is, with rose colored anthers, which dehisced pollen normally, were found to be D 1135, Badila, H 109, and occasionally Uba and U. D. 1. Illustrations of dissected flowers of the first four cane varieties can be seen in Figs. 2, 3, 4 and 5. The ovary and stigmas of a H 109 cane flower are shown in Fig. 6. Varieties which have been found to almost entirely, so far as observed, produce lemon-yellow anthers and no viable pollen are: Tip canes, Lahaina, Striped Mexican and Yellow Caledonia. A typical flower of Yellow Caledonia as grown on Oahu is shown in Fig. 7. No anthers are produced, but three stigmas are almost always present in each flower. Uba

Fig. 3. Fully mature flower of Badila cane. The three anthers, two stigmas and two lodicules can be seen distinctly. X 40.

Fig. 4. Fully developed cane flower of H 109. Anthers not yet dehiscing. Stigmas wilted slighted by microscope lamp. X 25.

and U. D. 1 canes could be grouped with these canes were it not for a very rare occurrence of dehiscing anthers. During the tasseling season of 1924, observations were made on several commercial varieties under laboratory conditions and the records, although incomplete, point to varietal differences in flowering activities which have been in part substantiated by the observations made during the season of 1925. These observations were made on 5 tassels of H 109, 7 tassels of D 1135 and a single tassel of Badila in the 1924 season. During 1925 all varieties were represented by 10 tassels, the first lot of tassels being observed under exposed conditions, at times in the rain, while those observed after December 7 were all kept under laboratory conditions. All were cut tassels preserved in sulfurous acid solution, which was changed daily. In Table 2 are recorded the hours of observed emergence of new flowers and dehiscence of pollen of self-fertile canes in both the seasons of 1924 and 1925.

Fig. 5. Fully developed complete flower of Uba cane. The lodicules are distinctly shown at the base of the flower. X 30.

Fig. 6. Stigmas and ovary of a single H 109 cane flower. X 40.

Fig. 7. A typical flower of the 1925 season of Yellow Caledonia, showing the aborted stamens and the well developed stigmas. X 40.

TABLE 2

Flowering Periods of Self-fertile Cane Varieties Observed in 1924

D 1135

Date	Emergence of First Flowers	First Pollen Cast	Heaviest Pollen Cast
Dec. 18, 1924	2:00 a. m.	5:00 a. m.	5:00 a. m.
" 20	5:00 a. m.	5:50 a. m.	
" 22	1:10 a. m.	1:30 a. m.	
" 3, 1925	6:00* a. m.	8:30 a. m.	
" 4	6:00 a. m.	7:00 a. m.	9:00 a. m.
" 5	5:00 a. m.	8:00 a. m.	
" 8	1:00 a. m.	2:00 a. m.	
" 9	3:00* a. m.	3:30 a. m.	
" 10	3:00* a. m.	3:10 a. m.	
" 11	4:00 a. m.		
" 12	2:30* a. m.	2:30 a. m.	
" 13	9:00* a. m.	9:00 a. m.	
" 15	5:00* a. m.	5:00 a. m.	
" 16	5:00 a. m.	6:00 a. m.	

H 109

Dec. 18, 1924	12:00 p. m.	8:00 a. m.	
" 20		8:00 a. m.	8:30 a. m.
" 22	3:00 a. m.		
" 23	12:10 a. m.	1:30 a. m.	
" 2, 1925	5:00* a. m.		
" 3	5:00* a. m.	8:00 a. m.	8:30 a. m.
" 4	5:25* a. m.	9:00 a. m.	9:00 a. m.
" 5	5:00 a. m.	7:00 a. m.	
" 8	1:00 a. m.		
" 9	3:50 a. m.		
" 10	3:30 a. m.		
" 11	5:00 a. m.		
" 12	4:30 a. m.		
" 13	9:00* a. m.		
" 15	6:00* a. m.		
" 16	6:00* a. m.		
" 17	6:00* a. m.		

Badila

Dec. 19, 1924	1:00 a. m.	3:00 a. m.	
" 20	5:00 a. m.	7:00 a. m.	8:00 a. m.
" 22	12:40 a. m.	1:00 a. m.	3:00 a. m.
" 23	12:10 a. m.		
" 12, 1925	3:00* a. m.	3:00* a. m.	
" 14	6:00* a. m.	6:00* a. m.	
" 15	6:00* a. m.	6:00* a. m.	
" 16	5:00* a. m.	5:00* a. m.	
" 17	5:15* a. m.	5:15* a. m.	

* Hours so marked indicate earliest observation made that day.

In studying Table 2 it is noted that certain cane varieties apparently bloomed earlier each morning in 1924 than during the season of 1925. This is not necessarily true, but simply indicates that no one was able to make a 24-hour daily study of the flowers during the latter season. The table does show, however, that flowers are well emerged by 5 a. m. under the usual conditions, even with rain present. On the other hand, rain may so restrain the dehiscence of pollen as to prevent it until 7 or 8 a. m. with certain varieties. Especially is this true with H 109 pollen, which normally dehisces pollen late in the morning.

In Table 3 are recorded the hours of observed flower opening of certain cane varieties which usually do not produce mature pollen grains. Each afternoon all open flowers, together with the supporting spikelet were trimmed from all tassels. All flowers observed during the ensuing night were necessarily newly opened flowers. No tassels of Striped Mexican cane could be obtained during the period of study of the 1925 season.

TABLE 3

Observed Hours of Opening of Flowers of Less Fertile Varieties

Varieties Used

Lahaina		Tip	
Date	Hours	Date	Hours
Dec. 20, 1924	5:00* a. m.	Dec. 19, 1924	1:00 a. m.
" 21	8:00* a. m.	" 20	4:30 a. m.
" 22	12:30 a. m.	" 21	8:00* a. m.
" 23	12:10 a. m.	" 22	3:00 a. m.
" 2, 1925	5:15* a. m.	" 23	12:10 a. m.
" 3	5:20* a. m.		
" 5	6:00* a. m.		
" 8	1:00 a. m.	Yellow Caledonia	
" 9	4:00* a. m.	Dec. 2, 1925	9:30 a. m.
" 10	3:40* a. m.	" 3	5:00 a. m.
" 11	6:00* a. m.	" 4	9:00 a. m.
" 12	2:30* a. m.	" 7	9:00 a. m.
Striped Mexican		" 11	5:20 a. m.
Dec. 21, 1924	12:00 p. m.	" 12	4:00 a. m.
" 22	12:00 p. m.		
Uba			
Dec. 11, 1925	3:00* a. m.	U. D. 1	
" 12	3:00* a. m.	Dec. 9, 1925	4:00* a. m.
" 15	6:40* a. m.	" 10	3:30* a. m.
" 16	5:40* a. m.	" 11	4:30 a. m.
" 17	7:00* a. m.	" 12	2:30* a. m.

The tabulated hours are in many cases not the earliest periods of flower emergence, but the results show that all self-sterile varieties, or those nearly so, are necessarily in a receptive condition nearly as soon as fertile pollen is available from self-fertile varieties. This point is more clearly shown in Table 4, which gives only the hours when open flowers were first noted daily during the 1925 season.

* Hours so marked indicate earliest observation made that day.

TABLE 4

Hours of First Observation of Open Flowers on Cane Varieties During 1925

Date 1925	Lahaina First Observed		H 109 First Observed		D 1135 First Observed	
	Open Flowers	Open Anthers	Open Flowers	Open Anthers	Open Flowers	Open Anthers
	a. m.	a. m.	a. m.	a. m.	a. m.	a.m.
Dec. 2	5:15	....	5:00	8:30	....	....
" 3	5:20	....	5:00	8:30	5:30	....
" 4	....	....	5:25	9:00	5:30	(Rare)
" 5	6:00	....	5:30	7:30	5:30	8:00
" 7	9:00	....	....	....	6:00	9:30
" 8	1:00	....	1:00	....	1:00	2:00
" 9	4:00	....	3:50	....	3:30	3:30
" 10	3:30	....	3:40	....	3:10	3:10
" 11	5:30	....	5:40	....	4:00	4:00
" 12	2:30	....	4:40	9:00	2:30	2:30
" 13	9:00	....	9:00	10:00	9:00	9:00
" 14	5:00	....	....	....	5:00	5:30
" 15	....	....	6:00	....	6:30	6:30
" 16	6:40	....	6:25	....	6:30	6:30
" 17	6:40	....	....	....	....	....

Date 1925	Yellow Caledonia First Observed		Uba First Observed		U. D. 1 First Observed		Badila First Observed	
	Open Flowers	Open Anthers	Open Flowers	Open Anthers	Open Flowers	Open Anthers	Open Flowers	Open Anthers
	a. m.	a. m.	a. m.	a. m.	a. m.	a. m.	a. m.	a. m.
Dec. 3	7:00	....	....	....	....	....	....	....
" 4	8:45	....	....	....	....	....	....	....
" 7	9:00	....	....	....	....	....	....	....
" 9	....	....	....	....	4:00	....	....	....
" 10	....	....	....	....	3:37	....	....	....
" 11	5:20	....	5:00	....	4:30	....	....	....
" 12	4:15	....	3:00	....	2:45	....	3:00	3:15
" 13	9:00	....	9:00	....	9:00	....	10:00	....
" 14	....	....	....	....	....	....	6:00	6:00
" 15	....	....	6:30	....	7:00	7:00	5:30	6:00
" 16	....	....	5:45	....	7:00	....	5:00	6:00
" 17	....	....	6:00	7:00	7:00	7:00	5:00	5:45

From a study of the periods of open flowers and dehiscing pollen as shown in Table 4, it is readily seen that D 1135 tassels may be used as male parents in crossing with Lahaina because the Lahaina flowers are in a receptive condition in the early hours of the morning, usually by 3 a. m. On the other hand, were H 109 to be used as male parent in a cross of H 109 and Lahaina the late appearance of H 109 pollen each morning would tend, in cases where the tassels were exposed to drying winds and sunshine before that time, to preclude cross fertilization, as the pollen grains would be shriveled before reaching the Lahaina stigmas. Also the possibility of crossing H 109 with Uba or U. D. 1 or Lahaina

would be favored by having the parent tassels growing in an enclosure or location where the direct rays of the sun were excluded until 9 a. m. and where high relative humidity could be maintained equally as late in the morning. Such a provision would tend to insure cross-fertilization and under such conditions the number of cross fertilized, viable seeds would be much greater than under less favorable conditions.

The rapidity of flower opening on young tassels is recorded here for two varieties on which counts of open flowers were made at intervals. The rate of opening of D 1135 flowers is shown in Table 5, while that of U. D. 1 is shown in Table 6.

TABLE 5

Showing Rate of Flower Opening of D 1135 Tassels in the Laboratory

	December 9, 1925				December 10, 1925			December 11, 1925		
	3:30	4:50	6:00	11:30	3:00	5:10	1:30	4:00	7:00	1:30
Tassel No.	a. m.	a. m.	a. m.	a. m.	a. m.	a. m.	p. m.	a. m.	a. m.	p. m.
1	...	...	...	...	...	...	...	...	...	...
2	35	55	100	186	27	57	100	33	72	116
3	15	60	150	229	13	165	197	100	170	171
4	32	...	...	...	14	125	231	200	200	200
5	...	51	100	150	4	124	265	150	200	205
6	4	150	...	170	13	122	154	75	120	125
7	10	160	...	255	9	90	172	160	300	363
8	100	...	...	...	7	75	85	50	90	100
9	4	30	38	56	2	12	25	65	140	141
10	15	35	40	78	2	17	46	50	152	322

The D 1135 tassels used for this test were cut December 7, 1925, and had no open flowers on them at the time they were brought into the laboratory. All open flowers were trimmed from the tassels each afternoon and counted.

It may be observed from Table 5 that flowering of D 1135 tassels is, under Hawaiian conditions, at its height between the hours of 5 and 7 a. m. The counts made on December 11, 1925, at 7 a. m. indicate, when compared with the counts made at 1:30 p. m. the same day, that the opening of flowers after seven o'clock is rare. It is unfortunate that hourly counts could not have been made during these studies. From this table it can be seen that the greatest number of flowers appeared previous to 7 a. m. and that the period between 5 and 7 a. m. is, under normal weather conditions, in the absence of rain, the best period for shaking pollen from D 1135 tassels directly on the female tassels which are to be pollinated. This would tend to insure the deposition of turgid pollen grains on receptive stigmas at that time and the germination of the pollen grains would naturally take place before the early morning sunshine could dry the grains or stigmatic surfaces. On the other hand, the flowers opening after 6 a. m. would be dehiscing viable pollen in protected localities much later in the morning and for crossing varieties which flowered later than 7 a. m. D 1135 pollen would be available even as late as 9 a. m. under such favorable conditions.

TABLE 6

Flowering History of U. D. 1 Cane Tassels

Tassels Cut December 8, 1925

Tassel No.	December 8 No. Open Flowers 4:30 p. m.	December 9, 1925 No. of Open Flowers 4:00 a. m.	5:00 a. m.	6:30 a. m.	2:00 p. m.	December 10, 1925 No. of Open Flowers 3:30 a. m.	5:45 a. m.	2:30 p. m.
1	50	+*	+	+	+	+	+	+
2	200	+	+	+	+	+	+	+
3	0	4	10	10	22	5	36	75
4	16	8	14	21	52	5	9	31
5	50	+	+	+	+	+	+	+
6	0	13	14	15	42	8	21	65
7	50	+	+	+	+	+	+	+

Tassel No.	December 11, 1925 No. of Open Flowers 5:45 a. m.	2:40 p. m.	December 12, 1925 No. of Open Flowers 2:45 a. m.	6:00 a. m.
1	+	+	+	+
2	+	+	+	+
3	24	43	30	+
4	5	28	21	+
5	+	+	+	+
6	28	66	40	+
7	+	+	+	+

In Table 6 the flowering of 7 tassels of U. D. 1 is shown. Tassels 1, 2, 5 and 7 produced so many open flowers on the second day that it was impossible to count them accurately. Tassels 3, 4 and 6, being younger tassels, flowered much more slowly, and the young flowers were counted at intervals as stated. No flowers were removed until late in the afternoon each day. It is noted that the greatest number of flowers appeared after 6 a. m., but with the large number of tassels under study it was impossible to make more counts during the forenoon. This variety of cane is, therefore, in an ideal condition, as far as stigma receptivity is concerned, for cross-fertilization between the hours of 5 and 7 a. m.

Typical Tassels of Commercial Cane Varieties

Some idea of the difficulty in making counts of open flowers on very young tassels may be obtained from the illustrations of typical cane tassels shown herewith. All the figures are one-fifth natural size.

Fig. 8 illustrates a very young D 1135 tassel which flowered but one morning. The small opened flowers may be distinguished on the upper left-hand side of the tassel. No open flowers can be seen on the lower half of the tassel. The reddish color of the open flowers aids in the counting process.

A more advanced flowering stage of cane tassels is shown in Fig. 9. This is a Badila tassel on which the large number of open flowers can be very clearly

* Note:—The plus sign (+) in the above table indicates that the number of flowers open at that time was so great that they were impossible to count accurately.

Fig. 8. Early flowering stage of D 1135 tassel. (One-eighth natural size.)

Fig. 9. Late flowering stage of Badila tassel. (One-eighth natural size.)

seen in profile against the gray background. A very difficult tassel to make flower counts on is the H 109, which is illustrated in Fig. 10. The open flowers are surrounded by numbers of bristling hairs which hide the flowers. At the lower left portion of the tassel illustrated, spikelets bearing unopened flowers can be observed. The same characteristics of bristling hairs and compact tassel are typical of Lahaina tassels, as shown in Fig. 11. Here the flowers are even more distinct than on the H 109, due to the bright red color of the stigmas. The large number of open flowers can be seen in this illustration near the left central portion of the tassel. A marked feature of these tassels in our laboratory studies was the tendency to remain partially enclosed in the sheath during the flowering period. This tendency is also noted in H 109 tassels, which shows the inheritance of this character from Lahaina, the female parent of H 109 cane.

A typical Yellow Caledonia tassel is shown in Fig. 12. These tassels were by far the largest under observation and produce only self-sterile flowers. Only a small number of flowers opened on these tassels during the period of observation.

Fig. 10. Tassel of H 109 cane. (One-eighth natural size.)

Fig. 11. Late flowering stage of Lahaina tassel. (One-eighth natural size.)

This variety is usually found with abortive flowers. No open flowers can be distinguished in the illustration. Another self-sterile type of tassel is illustrated in Fig. 13. This Uba tassel usually formed yellow sterile anthers, only a very few of the many open flowers illustrated having dehisced any pollen. The dark spots along the upper spikelets are the red stigmas of the open flowers. These tassels are decidedly whitish as compared to the reddish color of the D 1135 tassels.

In Fig. 14, a tassel of the progeny of a D 1135 and Uba cross is shown. This variety is known as U. D. 1 and the tassel shows the general Uba characteristics, being extremely hairy and of a gray color. The innumerable open flowers are seen at the upper portion of the tassel as dark spots along the spikelets. These dark spots are the protruding stigmas of the open flowers.

To Mr. D. M. Weller, of this Station, is due credit for the photomicrographs accompanying this paper.

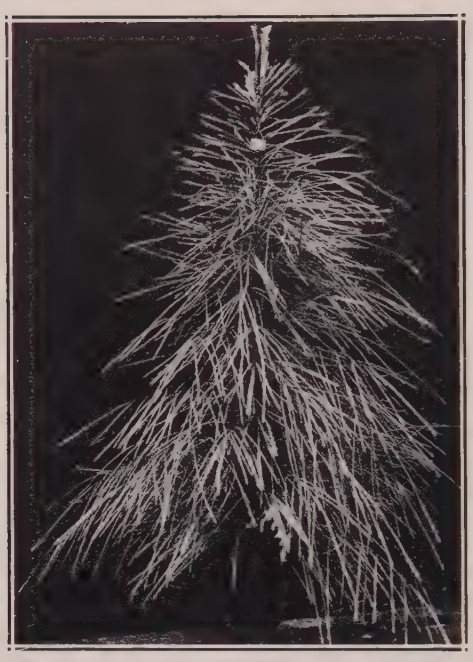


Fig. 12. Tassel of Yellow Caledonia cane.
(One-eighth natural size.)

Summary

1. Normal flowering of sugar canes is dependent upon high relative humidity, i. e., 80-90 per cent.

2. Rainfall does not hinder flowering but does inhibit pollen discharge as long as the flowers are saturated with water.

3. On both exposed tassels and those kept in the laboratory no flowers were found to open previous to midnight during any night of the study.

4. D 1135 tassels, used in this study as a standard, continued to open flowers from midnight until 7 a. m. each morning during the flowering period of the individual tassel.

5. The greatest number of flowers opening on single tassels during the nights of observation, opened between the hours of 3 and 7 a. m.

6. Heavy pollen casts could be obtained from D 1135 tassels, at 2, 3, 4, 5 and 6 a. m.

7. D 1135 canes are definitely self-fertile. Pollen dehiscence is usually concurrent with flower opening. Single flowers have been found to open, the discharged pollen make contact with the stigmas, germinate and the germ tube penetrate the stigmatic surface sufficiently to resist dislocation with dissecting instruments. All of this occurred within fifteen minutes elapsed time.

8. Self-fertile cane varieties or those having complete flowers with mature pollen grains, are found to be: D 1135, Badila, H 109, and occasionally Uba and U. D. 1.

Fig. 13. Advanced stage of flowering of Uba tassel. (One-eighth natural size.)

Fig. 14. Late flowering stage of U. D. 1 tassel. (One-eighth natural size.)

9. Self-sterile cane varieties, or those not having complete flowers, are found to be (usually) Tip canes, Lahaina, Striped Mexican and Yellow Caledonia.

10. The first flowers opening on D 1135, H 109, Badila, Lahaina, Striped Mexican and Tip canes are found between midnight and 3 a. m.

11. Anther dehiscence can be retarded on self-fertile varieties like D 1135 by sprinkling the tassels frequently during the period of flower emergence. In tests made in 1925, 100 per cent of the anthers of flowers opening any particular morning on the sprinkled tassels were restrained from discharging pollen until 9 a. m. Such methods could be adopted to induce crossing of two strongly self-fertile cane varieties.

12. Photomicrographs of sugar cane flowers are shown, as well as photographs of typical Hawaiian-grown commercial cane tassels.

Literature Cited

1. Brandes, E. W. In a letter to Mr. H. P. Agee, Director, Experiment Station, H. S. P. A., November 25, 1924.

2. de Calvino, Dr. Eva Mameli. Chaparra Agricola, Vol. 1, No. 11, March 20, 1925.

3. Verret, J. A., Kutsunai and others. Hawaiian Planters' Record, Vol. 29, No. 1, January, 1925.

Progress Report of Sugar Cane Pollen Studies

By D. M. Weller

Knowledge of the amounts of pollen shed, the viability of such pollen, the length of time during which viable pollen is shed, and the environmental factors influencing such pollen formation and viability has a direct and immediate application in the technique of cross-pollinating the various cane varieties commonly used for parent tassels. The knowledge gained by these studies, therefore, places the work of hybridization on a more accurate and precise basis.

Owing to the shortness of the cane tasseling season, approximately from November 1 to December 31, in these Islands, these studies could not be completed in one season and progress will necessarily be intermittent. The following is a *progress report* of cane pollen studies during the 1925 cane tasseling season.

Review of Methods for Determining Viability of Sugar Cane Pollen

Perhaps the method most commonly used for determining the viability of sugar cane pollen is that of applying a solution of iodine in potassium iodide. The resulting bluish-black coloration of the pollen grains following the application of the iodine solution has been interpreted by some to indicate viability, but by others to indicate merely maturity of the grains so colored. Those pollen grains appearing a yellowish-brown color are said to be non-viable or immature. It is now thought, however, that this reaction is not a certain indication of viability. It has been our experience that mature pollen grains which have become dry and wrinkled will not germinate. Such pollen grains, however, show a positive reaction by this method, for they swell in the iodine solution until they become turgid again and show the presence of numerous starch grains which become a deep bluish-black color. Wilbrink and Ledeboer (4) used this method to ascertain whether or not pollen grains of various varieties of cane matured. Mrs. Eva Calvino (2) says that the "presence of starch granules in the pollen grains is not sufficient to indicate conclusively its fertility," and concludes that in addition to the grains being "mature," and "containing starch granules" they must be "morphologically normal."

Germination of cane pollen has been attempted with some degree of success by placing the pollen grains on the stigmatic surfaces of the pistils of various plants, such as papaya and jimson-weed, *Datura stramonium*. At the cane breeding session of the Sugar Section of the Pan-Pacific Food Conservation Conference held in Honolulu, August, 1924, Dr. Mario Calvino told of success in germinating cane pollen by this method. The same method was also in use in Fiji, according to Mr. H. F. Clarke. Dr. E. W. Brandes stated that in Florida the stigmas of the flowers of the moon vine, a species of Ipomea, were being used for this purpose. While germinations of cane pollen have been obtained in this way, the method has the objection that the stigmas of any one of these plants are not necessarily standardized; failure to secure germinations may not be due to the non-viability

of the pollen, but to the character of the stigma used. At the South Johnstone Sugar Experiment Station in Australia (3) the stigmas of Hibiscus were used, but were found "too awkward to handle."

Another method of artificially germinating cane pollen is that of using artificial media, such as agar, sugar solutions, etc. Such germination media can be standardized, thus avoiding the criticism which may be made of the method of using the stigmas of plants. In 1910, Wilbrink and Ledeboer (4) found that pollen of a variety of Chunnee cane germinated "freely on a nutrition plate containing 30 per cent cane sugar and 2 per cent agar, but that of other cane varieties could not be brought to germinate on any nutrition plate." Mrs. Calvino states that she has "obtained germinations of pollen of two varieties by placing them on wheat flour soaked in a 30 per cent sucrose solution. The pollen tubes have reached a length of 88, 99 and 160 microns on such media, but the amount of germination is very low and the results cannot be considered as definite data. It is probable that we cannot obtain germinations in an artificial manner and shall have to be content with an examination of the pollen on the stigmas of the cane flowers." A method in use at the South Johnstone Sugar Experiment Station (3) was to cut a piece of filter paper to fit a microscope slide. A square hole, a little smaller than the size of a cover slip, was made in the filter paper. In this hole the pistils of cane flowers were placed. Pollen was dusted on the stigmas and a cover slip placed over the whole. The chamber thus formed was kept moist by cotton threads attached to the filter paper and leading to a small dish of water. The method was developed further by increasing the number of pistils per slide, but was too tedious to give large numbers of germinations from which to draw quantitative conclusions.

The trials made at this Station in recent years to germinate cane pollen on agar and other artificial media were unsuccessful. Various sugar solutions failed.

In November, 1924, at the suggestion of Dr. F. C. Newcombe, Mr. Barnum secured germinations in Petri dishes, in the covers of which were placed drops of water on bits of filter paper. Although germinations were secured, this method had not been entirely satisfactory because the factors of light, humidity and temperature were not controlled. It was purposed, therefore, to develop a method in which the factors of light, temperature and humidity would be known, thus eliminating all variables except the one of pollen viability.

Attempts to Germinate Pollen at Atmospheric Humidities Controlled by Sulfuric Acid Concentrations

Pollen was shaken from tassels onto cover slips, which were inverted and sealed with vaseline on shell vials with ground tops. These vials were half filled with different concentrations of sulfuric acid solutions which resulted in the air chambers of the vials having relative humidities of 100 per cent, 98 per cent, 96 per cent, etc., on down to 80 per cent, and were placed in a constant-temperature oven, at a known temperature, and light excluded.

On November 12, ten tassels of D 1135 and six of H 109, which had been cut and placed with the cut end in sulfurous acid solution on November 8, were brought into the laboratory. The opening of the flowers and the dehiscing of the

Fig. 1. A dissected cane flower of the variety H 109, showing a dehiscing anther and the mature pollen grains within. Pollen for the germination experiments was collected at this stage of the flowers' opening. X 40.

anthers was observed in order that the tassels might be shaken over the cover slips at the time of the shedding of the maximum amount of pollen (Fig. 1). This time was determined by counting under a binocular microscope the number of dehiscing anthers on branches from different parts of the tassel. When 80 to 90 per cent of the anthers were dehiscing, the tassels were held above a large moist chamber, on the bottom of which the cover slips were placed. By gently rapping on the branches with the handle of a dissecting needle, showers of pollen were discharged from the bursting anthers and deposited on the cover slips beneath. It is obvious that air drafts should be avoided during the process. The cover of the large moist chamber in which were placed from 12 to 15 drops of water on bits of filter paper was quickly replaced. The cover slips on which the pollen was deposited were then taken out of the moist chamber one by one (the cover of the moist chamber being replaced after each one), inverted and sealed on the vials containing the sulfuric acid solutions. One set of vials was immediately placed in the constant-temperature oven at 27.5° C. A duplicate set as a control was kept outside the oven at room temperature. Pollen from the six H 109 tassels was treated identically with the pollen from the D 1135 tassels.

After twelve hours these four sets of vials were examined without removing the sealed cover slips, by placing them individually under a binocular microscope having a magnification of X74. It was apparent from the number and size of the drops of condensed moisture on the cover slips and on the slides of the vials that there was a range of relative humidities in the vials gradually decreasing from 100 per cent on down to 90 per cent, where no moisture was apparent on the cover slips even under 74 magnifications.

The pollen grains also showed evidence of this range, for in the vial of 100 per cent humidity most of the pollen was bursted in the drops of moisture, a smaller per cent was bursted in the drops of moisture in the vial of 98 per cent humidity, and so on down to the vial of 92 per cent humidity, below which point

there were no drops of condensed moisture on the cover slips and the pollen grains were shriveled, evidently from drying. The pollen grains on the cover slips not in contact with condensed moisture were turgid, somewhat swollen, and glistening.

In the set of vials containing the D 1135 pollen at 27.5° C. and the control at room temperatures there were no germinations. The same was true for the set of H 109 and its control at room temperature.

Attempts to Germinate Pollen in Watch Glasses and Micro-Culture Slides Over Sulfuric Acid Solutions

Because no germinations resulted from the trial above it was surmised that the viable pollen was heavier than the non-viable and, being too heavy to stick to the cover slips, had fallen off. The next morning, therefore, November 14, pollen from the D 1135 tassels was dusted into watch glasses, which were set on thick micro-culture slides in Petri dishes. The sulfuric acid solutions were poured into the Petri dishes around the micro-culture slides. Two sets were made with a range of humidity from 100 per cent down to 80 per cent in the same way as with the vials of the experiment above. The covers of one set were sealed with vaseline; those of the other were unsealed. Both were kept at room temperature. Examination after twenty-four hours showed no germinations.

On November 16, pollen from the D 1135 tassels was dusted onto cover slips which were inverted and sealed with vaseline on micro-culture slides, in each of which was placed a single drop of sulfuric acid solution used in the two previous experiments on a small bit of filter paper placed on the bottom of the chamber. Two sets were made. One was placed in the constant-temperature oven at 27.5° C. and the other on the laboratory table where the temperature ranged from 20° C. to 27° C. Examination after twelve hours showed no germinations in either.

This experiment was modified by dipping small bits of filter paper into water instead of sulfuric acid solution, the method described by Badami (1) being used, but with negative results.

Germinations in Petri Dishes With Drops of Moisture Inside Their Covers Used as a Control Method

It was decided, therefore, to use the method of placing moist bits of filter paper inside the covers of Petri dishes as being the best method at hand and to learn why it had not always resulted in germinations; also to develop it so that it could be used as a control on the method described in the first experiment where the factors of light, humidity and temperature were known. On November 17, pollen from the D 1135 tassels used above (cut November 8) was dusted into Petri dishes, the lids of which contained 1, 2, 3, 4, 5, 6 and 7 drops of water. A duplicate set was made with pollen from D 1135 tassels cut November 13. After twelve hours, germinations (Fig. 2) were found in the second set, but none were found in the first set. These germinations occurred in the dish with 5 drops and the one with 6 drops. *Datura* stigmas were placed in Petri dishes and pollen from the second set of tassels shaken over them. Their covers contained

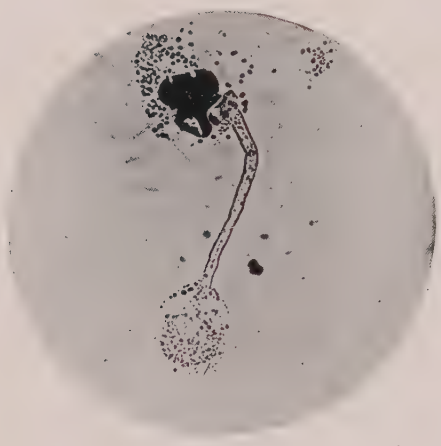


Fig. 2. A germinated pollen grain of D 1135 just before it ruptured. This germination took place in the bottom of a Petri dish in the cover of which were placed five drops of water on small bits of filter paper. X 130.

0, 1, 2, 3 and 4 drops of water. No germinations occurred on the *Datura* stigmas, but germinations occurred on the bottom of the dish having 4 drops of water.

The Relation of Viability of Pollen to the Length of Time Tassels Have Been Cut

Since no germinations had been obtained with pollen from the first set of tassels on the fifth to ninth days after cutting, and germinations were obtained with pollen from the second set on the fourth day after cutting, it was surmised that the obtaining of germinations had a direct relationship to the freshness of the tassels. These tassels were, therefore, discarded and a new set of D 1135 tassels cut on November 18.

On November 19, Petri dishes with 3, 4, 5, 6 and 7 drops of water in their covers were used to catch pollen from the D 1135 tassels cut the preceding day. Germinations resulted in the dish with 5 drops. The temperature was 76° F.

On November 21, the second day, germinations were again obtained with pollen from these tassels in Petri dishes with 5 drops of water. A second set of Petri dishes in the oven at 27.5° C. (81½° F.) showed none.

Ten D 1135 tassels and ten H 109 tassels cut on December 1, on which the first flowers opened on December 2, gave germinations on December 2, 3 and 4.

Ten uniform D 1135 tassels, fully emerged from the sheath, were cut and put in sulfurous acid solution on December 7. Pollen from these tassels germinated as shown in Table I. Each tassel was given a number and germination tests conducted separately for each.

At this stage of the work it was seen that in order to get a comparison of methods, a *quantitative measure* of the germinating pollen must be available. For this reason counts of germinating pollen were made and percentages of germination determined. The total number of pollen grains and the number of germinating pollen grains on ten microscope fields were counted for each tassel.

TABLE I

Showing Decrease in Viability of Pollen on Succeeding Days From 10 Tassels of D 1135 Cane; These Tassels Were Entirely Emerged from the Sheath When Cut

Number of days after cutting tassels	Total number pollen grains on 100 microscope fields	Germinations	
		Number	Percentage
1	1745	60	3.4
2	2568	41	1.59
3	1196	2	0.16
4	640	0	0.0
5	1314	4	0.3

Ten uniform D 1135 tassels, half emerged from the sheath, were also cut December 7. Pollen from these tassels germinated as shown in Table II.

TABLE II

Showing Decrease in Viability on Succeeding Days of Pollen from 10 Tassels of D 1135 Which Were Only Half Emerged from the Sheath When Cut

Number of days after cutting tassels	Total number pollen grains on 100 microscope fields	Germinations	
		Number	Percentage
1	365	13	3.5
2	1412	4	0.2
3	432	5	1.1
4	883	0	0.1
5	3111	10	0.3

Ten uniform D 1135 tassels, cut December 5, kept in water until December 7, and then transferred to sulfurous acid solution and brought into the laboratory showed germinations as recorded in Table III.

TABLE III

Showing Results of Germinations of Pollen from Ten D 1135 Tassels Held Two Days in Water Before Transferring Them to Sulfurous Acid Solution

Number of days after cutting tassels	Total number pollen grains on 100 microscope fields	Germinations	
		Number	Percentage
3	76	0	0.0
4	1335	4	0.29
5	1159	0	0.0
6	1462	4	0.27
7	893	0	0.0

From the results shown in Tables I, II and III, it seemed apparent that with increasing age after cutting, the tassels produced a smaller percentage of viable pollen. This led to the reconsideration of the factors of humidity and other environmental factors for germination, using pollen from freshly cut tassels for such tests.

The Influence of the Factors of Temperature and Humidity Upon Germination of Cane Pollen

In considering further a method of germinating cane pollen it was noted that in the previous trials with the vials of sulfuric acid solutions, the temperature in the constant-temperature oven was 27.5° C. (81½° F.) and that the tem-

perature of the laboratory would change from the minimum temperature of the preceding night from 62° F. or 68° F. to 75° F. by 9 a. m. and rise to 78° F. or 80° F. by noon, according to the recorded readings of the maximum and minimum thermometer in the laboratory. It was further noted that, when germinations had been obtained in Petri dishes, the temperature was recorded as being 68° F. or 70° F. In view of these facts it was decided to try again the sulfuric acid solutions with fresh pollen.

On December 15, pollen from Badila tassels cut the preceding day was used. Three constant-temperature ovens were maintained at 22° C., 24° C. and 25.5° C., respectively. Four sets of vials with sulfuric acid solutions resulting in relative humidities of 96°, 94°, 92° and 90° were made. One set was placed in each oven and the fourth at room temperature as a control. The results are as shown in Table IV. (See also Figs. 3 and 4.)

It is seen from Table IV that at 22° C., the maximum germination was 5.1 per cent at a relative humidity of 96 per cent. At a temperature 2 degrees higher, 24° C., the maximum germination (4.3 per cent) took place at a relative humidity of 94 per cent and that, at a temperature of 25.5° C., the maximum germination (3.4 per cent) took place at a relative humidity of 92 per cent. In other words, as the temperature was increased the optimum relative humidity decreased and as the temperature was increased above 22° C. the maximum percentage of germinations decreased.

On December 16, pollen from five D 1135 tassels cut the preceding day showed germinations as recorded in Table V.

From the tabulations shown in Tables IV, V and VI, it is seen that the results from both Badila pollen and D 1135 pollen were the same, i. e., as the temperature increased the relative humidity, at which maximum germination occurred, de-

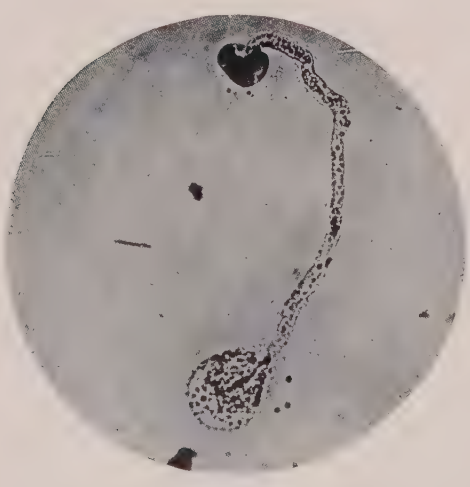


Fig. 3. A germinated pollen grain of D 1135 just before rupturing. This germination took place in a sealed vial of sulfuric acid solution at a relative humidity of 96 per cent and at a temperature of 22° C. Pollen tubes produced under these conditions attained a greater length than those produced in Petri dishes, as shown in Fig. 2. X 140.

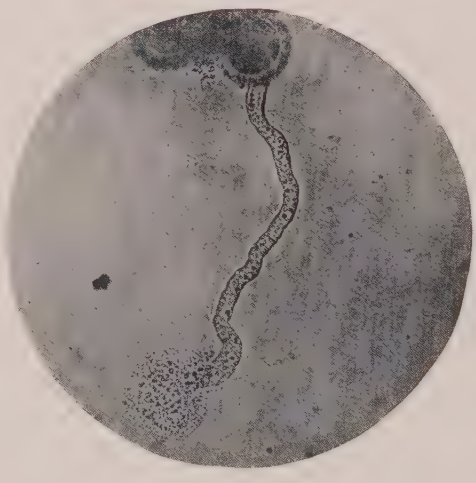


Fig. 4. A pollen grain of D 1135, germinated in the same way as that of Fig. 2, just after it ruptured. X 280.

TABLE IV

Showing Germinations of Pollen From Badila Tassels at Different Temperatures and Humidities: Tassels Cut the Preceding Day

Relative humidity	22° C.			24° C.			25.5° C.			Vials at room temperature		
	No. of pollen grains on 10 microscope fields	Germination		No. of pollen grains on 10 microscope fields	Germination		No. of pollen grains on 10 microscope fields	Germination		No. of pollen grains on 10 microscope fields	Germination	
		No.	Percentage		No.	Percentage		No.	Percentage		No.	Percentage
96	251	13	5.1	277	2	0.7	126	0	0.0	266	2	0.7
94	244	11	4.5	250	11	4.3	123	1	0.8	417	0	0.0
92	482	3	0.6	308	10	3.2	204	7	3.4	306	0	0.0
90	331	6	1.8	184	0	0.0	442	14	3.1	462	0	0.0
Total.....	1308	33	2.5	1019	23	2.2	895	22	2.4	1451	2	0.1

TABLE V

Showing the Relative Effects of Temperature and Humidity on Germination of Pollen From Five D 1135 Tassels Cut the Preceding Day

Relative humidity	22° C.			24° C.			26° C.			Vials at room temperature		
	No. of pollen grains on 10 microscope fields	Germination		No. of pollen grains on 10 microscope fields	Germination		No. of pollen grains on 10 microscope fields	Germination		No. of pollen grains on 10 microscope fields	Germination	
		No.	Percentage		No.	Percentage		No.	Percentage		No.	Percentage
96	366	6	1.6	151	1	0.6	272	2	0.7	199	0	0.0
94	187	1	0.5	266	4	1.5	105	1	0.9	123	0	0.0
92	172	1	0.5	125	2	1.6	206	0	0.0	185	0	0.0
90	204	1	0.4	201	1	0.49	213	3	1.3	84	0	0.0
88	124	0	0.0	179	1	0.55	130	0	0.0	76	0	0.0
Total.....	1053	9	0.85	922	9	0.97	926	6	0.64	667	0	0.0

TABLE VI

Showing the Relative Effects of Temperature and Humidity on Germinations of Pollen From the Five D 1135 Tassels of Table V the Second Day After Being Cut

	22° C.			24° C.			26° C.			Vials at room temperature		
Relative humidity	No. of pollen grains on 10 microscope fields	Germination No.	Germination Percentage	No. of pollen grains on 10 microscope fields	Germination No.	Germination Percentage	No. of pollen grains on 10 microscope fields	Germination No.	Germination Percentage	No. of pollen grains on 10 microscope fields	Germination No.	Germination Percentage
96	196	3	1.5	102	0	0.0	203	0	0.0	168	0	0.0
94	114	0	0.0	274	1	0.3	297	0	0.0	460	0	0.0
92	173	0	0.0	265	1	0.3	366	0	0.0	251	0	0.0
90	143	0	0.0	229	0	0.0	136	0	0.0	177	0	0.0
88	149	0	0.0	147	0	0.0	170	0	0.0	183	0	0.0
Total.....	775	0	0.0	1017	2	0.19	1172	0	0.0	1239	0	0.0

creased; and that at room temperature (approximately 27° C.) little or no germinations occurred. This suggests the existence of an optimum absolute humidity as well as an optimum temperature.

Effect of Carbon Dioxide and Oxygen on Pollen Germination

Since during the hours just before sunrise, at the time of anther dehiscence of cane flowers, and pollen germination, there is usually a heavy respiration of carbon dioxide from the cane plant, the thought occurred that the concentration of carbon dioxide or oxygen in the air might have an influence on pollen germination. To determine such effect, therefore, of carbon dioxide and oxygen on the germination of cane pollen, vials of sulfuric acid solution were used as in the preceding experiments. On December 29, pollen was obtained from a tassel of H 109 cut the preceding day. Through the sulfuric acid solution of each vial in one set, one bubble of carbon dioxide was passed. Through the acid of a second set, five bubbles of carbon dioxide were passed and through the acid of a third set, ten bubbles were passed. To the solutions of a fourth set, five drops of hydrogen peroxide were added; and to the solutions of a fifth set, ten drops of hydrogen peroxide were added. A sixth set untreated was kept as a control over the other five sets. These six sets of vials were placed in the oven at 22° C. The carbon dioxide and the hydrogen peroxide were added to the vials immediately before the cover slips were sealed on the vials and, being heavier than air, would not volatilize into the air quickly. Table VII shows the germinations at the different concentrations of these gases.

TABLE VII

Showing Lessening of Pollen Germination With Increasing Concentrations of Carbon Dioxide and Oxygen

Amount	No. of pollen grains on 10 microscope fields	Germinations	
		Number	Percentage
Normal air as control	620	12	1.9
1 bubble carbon dioxide	566	4	0.7
5 bubbles carbon dioxide	826	8	0.9
10 bubbles carbon dioxide	495	0	0.0
5 drops hydrogen peroxide	598	1	0.16
10 drops hydrogen peroxide	627	0	0.0

On the second day after cutting, pollen from the same tassel germinated as shown in Table VIII.

TABLE VIII

Showing Lessening of Pollen Germination With Increasing Concentrations of Carbon Dioxide and Oxygen

Amount	No. of pollen grains on 10 microscope fields	Germinations	
		Number	Percentage
Normal air as control	653	17	2.4
1 bubble carbon dioxide	629	13	2.0
5 bubbles carbon dioxide	554	3	0.5
10 bubbles carbon dioxide	539	0	0.0
5 drops hydrogen peroxide	511	0	0.0
10 drops hydrogen peroxide	148	0	0.0

From the results shown in Tables VII and VIII, it is seen that carbon dioxide and oxygen in the amounts used in these experiments have an inhibiting effect upon the germination of cane pollen. Under the microscope the pollen grains from the vials containing the carbon dioxide appeared to be somewhat darkened while those from the vials containing the oxygen appeared to be bleached.

Trials With Sugar Solutions

On January 2, pollen from a tassel of H 109, cut on December 30, was germinated over sulfuric acid solutions in one set of vials. On the cover slips of a second set was placed one drop of a 10 per cent solution of cane sugar. Both sets were placed in a constant-temperature oven at 22° C. The results of germinations are shown in Table IX.

TABLE IX

Showing the Germinations of Pollen of a Two-day Old Tassel of H 109 in the Presence of One Drop of a 10% Cane Sugar Solution

	Control			1 Drop of 10% sugar solution		
Relative humidity	No. pollen grains on 10 microscope fields	Germinations No.	Germinations Percentage	No. pollen grains on 10 microscope fields	Germinations No.	Germinations Percentage
100	45	2	4.4	110	0	0.0
98	214	3	1.4	268	2	0.7
96	197	0	0.0	159	2	1.2
94	82	1	1.2	107	0	0.0
92	232	2	0.8	125	0	0.0
90	125	2	1.5	236	1	0.4
88	147	0	0.0	112	0	0.0
Total.....	1042	10	0.95	1117	5	0.44

It is to be noted that the germinations in the second set did not occur in the drops of sugar solution, but in the drops of condensed moisture elsewhere on the cover slips. Apparently this sugar solution had an inhibiting influence on germination. The determining of whether or not this would be true for solutions of other sugars or for solutions of other concentrations of cane sugar will have to be determined at a later date.

The Viability of Pollen from Cut Tassels as Compared With that of Pollen from Growing Tassels

It was next thought desirable to compare the viability of pollen from cut tassels with that of those growing in the field. It was planned, therefore, to test out the pollen of ten tassels growing in the field with that of ten cut tassels. Because of the lateness of the season, these tassels could not be obtained. However, two H 109 tassels were found and used in the following experiment. Since cut tassels have been used so often previously, germination tests were made for two days only with pollen from the cut tassel. Tests with pollen from the growing tassel were made on the first, third, sixth and ninth days. The pollen from both tassels was placed over sulfuric acid solutions and maintained in a constant-temperature oven at 22° C. The results are shown in Table X.

TABLE X

Showing the Relative Germination of Pollen From a Growing Cane Tassel and That From a Cut Tassel at 22° C. and at Different Relative Humidities

A—Growing Tassel

Relative humidity	First Day			Second Day			Sixth Day			Ninth Day		
	No. of pollen grains on 10 microscope fields	Germinations		No. of pollen grains on 10 microscope fields	Germinations		No. of pollen grains on 10 microscope fields	Germinations		No. of pollen grains on 10 microscope fields	Germinations	
		No.	Per-centage		No.	Per-centage		No.	Per-centage		No.	Per-centage
100	...	..	....	140	11	7.8	330	18	5.4	50	3	6.0
98	20	3	15.0	140	10	7.1	309	12	3.8	119	5	4.2
96	15	1	6.6	144	4	2.7	334	5	1.1	77	3	3.8
94	17	0	0.0	179	8	4.4	275	3	1.0	62	2	3.2
92	25	0	0.0	87	1	1.1	105	1	0.9	124	2	1.6
90	30	1	3.3	103	6	5.8	327	0	0.0	84	0	0.0
Total.....	107	5	4.6	793	40	5.04	1680	39	2.3	516	15	2.9

B—Cut Tassel

	First Day			Second Day		
98	191	4	2.0	278	7	2.5
96	144	1	0.6	121	7	5.7
94	177	5	2.8	27	2	2.0
92	41	2	4.8	89	1	1.2
90	67	0	0.0	77	0	0.0
Total.....	620	12	1.9	653	17	2.6

TABLE XI

Showing the Relative Germination of Pollen From a Growing Cane Tassel of D 117 and That From Two Cut Tassels at 22° C. and at Different Relative Humidities

A—Growing Tassel

Relative humidity	First Day: No. of pollen grains on 10 microscope fields	First Day: Germinations No.	First Day: Germinations Percentage	Second Day: No. of pollen grains on 10 microscope fields	Second Day: Germinations No.	Second Day: Germinations Percentage	Sixth Day: No. of pollen grains on 10 microscope fields	Sixth Day: Germinations No.	Sixth Day: Germinations Percentage
100	69	2	2.8	56	2	3.5	40	1	2.5
98	73	1	1.3	93	0	0.0	133	0	0.0
96	71	1	1.4	91	0	0.0	39	0	0.0
94	81	2	2.4	77	0	0.0	28	2	7.1
92	34	0	0.0	80	0	0.0	131	0	0.0
90	36	0	0.0	41	0	0.0	33	0	0.0

B—Cut Tassel

	First Day			Second Day			Fourth Day		
100	96	1	1.0	49	0	0.0	162	1	0.6
98	42	0	0.0	79	0	0.0	92	0	0.0
96	175	0	0.0	149	3	2.0	85	0	0.0
94	100	1	1.9	118	0	0.0	72	0	0.0
92	106	0	0.0	102	0	0.0	95	1	1.0
90	61	0	0.0	106	0	0.0	75	0	0.0

Two D 117 tassels cut and placed in sulfurous acid solution and one set cut but growing gave germination results the following day as shown in Table XI.

From Tables X and XI it is seen that the percentage of germination of pollen from growing tassels is much higher than that of pollen from cut tassels, and also that the pollen from the growing tassels is viable over a longer period of days than that from cut tassels. From Table X it is seen that a 15 per cent germination was obtained with pollen from a growing tassel on the first day after cutting. This is the highest percentage of germination obtained during the season. It is also seen that a 6.0 per cent germination was obtained from the same tassel on the ninth day after cutting. This is a higher percentage than was ever obtained from a cut tassel even on the first day after cutting, 5.7 per cent being the highest germination obtained with pollen from cut tassels. From Table XI it is seen that a 7.1 per cent germination and a 2.5 per cent germination was obtained from pollen from a D 117 tassel six days after cutting.

Conclusions

1. Knowledge of the amounts of pollen shed, the viability of such pollen, the length of time during which viable pollen is shed, and the environmental factors influencing such pollen formation and viability has a direct and immediate application in the technique of cross-pollinating the various cane varieties commonly used for parent tassels.

2. Methods for determining viability of sugar cane pollen have not been satisfactory because (1) they do not discriminate between viability and maturity as, for example, the iodine method; (2) they are not adapted mechanically for securing counts in large numbers so that viability may be determined upon a quantitative basis as, for example, the method of using the stigmatic surfaces of various plants such as *Hibiscus, Ipomea* and *Datura* and because they are not standardized, i. e., the stigmatic surfaces of these plants are themselves variable and failure of pollen to germinate can be as easily ascribed to the character of the stigmas as to the non-viability of the pollen.

3. Methods of using nutritive media, agar, sugar solutions, etc., are adapted to the securing of quantitative data; in them the contents of the media themselves, temperature and light can be controlled, but because the factor of humidity is uncontrolled, comparative data cannot be secured.

4. The method of using different concentrations of sulfuric acid solutions in sealed vials to secure known humidities is a convenient and satisfactory method of securing quantitative data because the factors of humidity, temperature and light are known.

5. Temperature and humidity have a definite effect upon the percentage of germinations of sugar cane pollen. The optimum temperature was 22° C., at which temperature the maximum germinations occurred at a relative humidity of 96 per cent. If the temperature was raised, the relative humidity at which the maximum number of germinations occurred was lowered, suggesting an optimum absolute humidity as well as an optimum temperature.

6. The percentage of pollen germinations from cut tassels decreases rapidly from 5 or 6 per cent on the first day after the tassel is cut and placed in sulfurous acid to a fraction of 1 per cent on the third or fourth day.

7. A higher percentage of viable pollen is shed from growing tassels than from cut tassels and is shed for a greater number of days. The maximum percentage of viable pollen from growing tassels was 15 per cent, as compared with 5.7 per cent from cut tassels; a 6 per cent germination was obtained with pollen from a growing tassel on the ninth day as compared with a 5.7 per cent germination from cut tassels on the first day, which rapidly decreases to a fraction of a per cent on the third or fourth day.

In conclusion the writer would like to take advantage of this opportunity of thanking Mr. H. Atherton Lee for the idea of conducting these experiments upon a quantitative basis and for his many helpful suggestions. Appreciation is also extended to Mr. R. H. King, of the sugar technology department, for the suggestion of using, and for the preparation of, sulfuric acid solutions prepared according to data compiled by Wilson (5).

Literature Cited

1. Badami, V. K. R. The International Sugar Journal, Vol. 27, No. 319, p. 358, July, 1925.

2. Calvino, Mrs. Eva M. Notes on the Fertility of Cane Flowers. Chaparra Agricola, Vol. 1, No. 3, 1924.

3. Cottrell-Dormer, W. and McWalters. Studies on Fertility of Sugar Cane Flowers. South Johnstone Sugar Experiment Station, 1924. Queensland Agricultural Journal, September, 1924, p. 248.

4. Wilbrink, G., and Ledeboer, F. De Geslachtelijke Voortplanting Bij Het Suikerriet. Archief voor de Suikerindustrie in Nederlandsch-Indië. Jaargang XIX, 1 Deel. 1911.

5. Wilson, R. E. Humidity Control by Means of Sulfuric Acid Solutions, with Critical Compilation of Vapor Pressure Data. The Journal of Industrial and Engineering Chemistry. April, 1921, pp. 326-331.

Sugar Prices

96° Centrifugals for the Period March 19, 1926, to June 15, 1926

Date	Per Pound	Per Ton	Remarks
Mar. 19, 1926	3.975¢	$79.50	Porto Ricos, 3.99, 3.96.
" 20	3.96	79.20	Cubas.
" 23	3.945	78.90	Cubas, 3.96; Porto Ricos, 3.93.
" 24	3.93	78.60	Porto Ricos.
" 25	3.96	79.20	Cubas.
" 26	4.02	80.40	Cubas.
" 27	4.05	81.00	Porto Ricos.
" 30	4.035	80.70	Cubas, 4.05, 4.02.
" 31	4.05	81.00	Cubas.
April 1	4.08	81.60	Porto Ricos.
" 6	4.065	81.30	Porto Ricos, 4.05, 4.08.
" 7	3.99	79.80	Cubas, 3.96, 4.02.
" 13	4.065	81.30	Porto Ricos, 4.08; Cubas, 4.05.
" 15	4.125	82.50	Cubas, 4.11, 4.14.
" 17	4.14	82.80	Cubas.
" 20	4.095	81.90	Cubas, 4.08; Porto Ricos, 4.11.
" 21	4.14	82.80	Cubas.
" 24	4.195	83.90	Cubas, 4.18, 4.21.
" 26	4.24	84.80	Cubas, 4.21, 4.27.
" 28	4.18	83.60	Cubas.
May 4	4.16	83.20	Cubas, 4.14; Porto Ricos, 4.18.
" 6	4.175	83.50	Porto Ricos, 4.14; Cubas, 4.21.
" 7	4.21	84.20	Cubas.
" 8	4.24	84.80	Porto Ricos, 4.21, 4.24, 4.27.
" 10	4.27	85.40	Cubas.
" 11	4.255	85.10	Porto Ricos, 4.24, 4.27.
" 14	4.14	82.80	Porto Ricos.
" 17	4.11	82.20	Cubas.
" 18	4.08	81.60	Porto Ricos.
" 20	4.14	82.80	Porto Ricos.
" 26	4.21	84.20	Cubas.
June 1	4.14	82.80	Cubas.
" 4	4.125	82.50	Cubas, 4.14; Porto Ricos, 4.11.
" 7	4.11	82.20	Porto Ricos.
" 9	4.095	81.90	Spot Philippines, 4.08; Porto Ricos, 4.11
" 10	4.11	82.20	Cubas.
" 14	4.125	82.50	Cubas, 4.14, 4.11.
" 15	4.16	83.20	Cubas, 4.14, 4.18.